

**CHILDHOOD PEDESTRIAN MORTALITY IN JOHANNESBURG, SOUTH  
AFRICA: MAGNITUDE, DETERMINANTS AND NEIGHBOURHOOD  
CHARACTERISTICS**

by

**Abdulsamed Bulbulia**

submitted in accordance with the requirements for the degree of

**DOCTOR OF PHILOSOPHY**

in the subject

**PSYCHOLOGY**

at the

University of South Africa

Supervisor: Prof Ashley van Niekerk

Co-supervisor: Prof Martin Terre Blanche

November 2015

## DECLARATION

I declare that this thesis, **Childhood Pedestrian Mortality in Johannesburg, South Africa: Magnitude, Determinants and Neighbourhood Characteristics**, is my own work, and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.



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Abdulsamed Bulbulia

30 March 2016

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Date

## DEDICATION

*Dedicated to all our children who have passed on, and to the safety of children present and  
future*

*“la vida primero, los autos segundos”* (life first, cars second)

(Evo Morales – President of Bolivia)

*“They paved paradise and put up a parking lot”*

(Joni Mitchell – Singer)

*Children’s lives matter*

## ACKNOWLEDGEMENTS

The completion of this thesis may be attributed to the assistance of various institutions, colleagues, families and friends. I would like to express my sincere gratitude and appreciation to the following:

The Institute for Social and Health Sciences (ISHS), University of South Africa and the South African Medical Research Council-University of South Africa Violence, Injury and Peace Research Unit (VIPRU).

My supervisors, Professors Ashley van Niekerk and Martin Terre Blanche; I am grateful for your supervision, patient and critical counsel and guidance throughout this doctoral journey. My heartfelt gratitude to you always for your collective contributions, and for ensuring the completion of this thesis. It is our collective achievement.

Professor Mohammed Seedat, mentor, colleague, friend and brother, I have been blessed with your unique collegiality, camaraderie and brotherly nurturance and guidance throughout most of my secular and spiritual learnings in life. I wish to express my sincere gratitude to you for motivating me to always produce our best, to succeed, and to remain humble. May you always be blessed and enveloped in the Almighty's mercy and benevolence.

Professor Sandy Lazarus, thank you for sharing your amazing academic and community experiences. Your compassionate and participatory disposition has left an indelible imprint on me. You embody an authentic community soul and spirit.

Dr Shahnaaz Suffla, an amazing and endearing friend, astute academic, and a motivational and inspirational colleague. *Jazakallah* (Almighty reward you) for your invaluable assistance.

Professor Shrikant Bangdiwala for making statistics a fun and creative learning experience. Thank you also for your willingness to share your expertise and assist me, and to Sarah Marks, thank you for volunteering your statistical skills.

Professor Rajen Govender, I am ever thankful for your statistical acuity and forbearance with a statistical novice.

Umesh Bawa, thank you for being my brother and friend and for your selflessness. You are a blessed gift in my life. You soon will be revelling in the completion of your thesis.

Rashid, Zooks, Siraj, Rafique, Ashraf, Umie, Ashfaak and Baka, among others, my warm thanks for all your brotherly love and support.

Najuwa Arendse, my everlasting gratitude always for your selfless accessibility and multi-skilled expertise.

Ghouwa Ismail and Naiema Taliep, thank you for your refreshing and heart-warming collegial friendships, and may your doctoral journeys be both memorable and successful.

Nancy Hornsby and Karin Pretorius, my thanks to you both for your expertise in statistics, and to Hilton Donson, thank you for your initial statistical support and collegiality.

My thanks to the National Injury Mortality Surveillance Team, and also to the forensic pathologists for sharing their committed expertise and services.

Anton Delport, my thanks for your kind collegial assistance with referencing.

To my colleagues from ISHS and VIPRU, thank you for your collegial support and amazing friendships.

My gratitude to Mildred, Royal, Jems, Lyndsey, Babsy, Peteke, Lu Anne, Kopano and Anesh for your endearing collegiality and friendships, and to Anthony, Sumaya, Annelise and Madeleine for making our working lives pleasant, and creating a conducive haven in which to work.

The Bulbulia, Jeewa, Seedat, Suffla, Williamson, and Cara families, your prayers, culinary delights and love is a constant in my life.

Beautiful friends, an everlasting blessing ...

My thanks to the communities of Strand (Western Cape) and Johannesburg, and who shared in this collective journey – I embraced your experiences and wisdom, and am forever grateful.

My beloved parents, and brother, may all your souls be at peace, and my deepest love and gratitude always.

Mothers Seedat and Bawa, may your souls also be at peace – my appreciation of you both is infinite.

Above all, I am thankful to the Almighty for His guidance, and I pray for the continuous blessings of beneficial knowledge, and the granting of wisdom.

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## **ABSTRACT**

Child pedestrian injury and mortality is an issue of significant public health concern in the City of Johannesburg, Gauteng, in South Africa. Since there is a paucity of studies in the last decade or more on fatal childhood traffic and non-traffic injuries in Johannesburg, this study aspires to address the disproportion in this domain of research, and provide more recent, and comprehensive empirical evidence over a ten-year period. The overarching aim of this study was to describe and examine the magnitude, circumstances, and neighbourhood characteristics of fatal pedestrian injuries among children (0-14 years) in Johannesburg for the period from 2001 to 2010. More specifically, the objectives of the study were: firstly, to provide a comprehensive epidemiological description of the magnitude, trends and occurrence of pedestrian mortality among children; secondly, to describe and examine the epidemiology of child pedestrian mortality in relation to children as motor vehicle passengers; thirdly, to describe and examine child pedestrian mortality in relation to non-traffic injuries, in particular, burns and drowning; and fourthly, to assess the influence of neighbourhood characteristics on child pedestrian mortality. The study conceptualised pedestrian road safety within an ecological systems framework. The study used quantitative descriptive, and multivariate logistic regression methods of analysis to examine child pedestrian mortality data. The study drew on data from the National Injury Mortality Surveillance System (NIMSS) and the Census 2001. The main findings indicated that black, male children aged 5 to 9 years (11.02/100 000) are the most vulnerable, and that mortality occurred predominantly during the afternoons and early evenings (12h00-16h00 and 16h00-21h00), over weekends, during school holidays, and to a lesser extent, during non-holiday months. In addition, neighbourhood characteristics that reflected concentrations of disadvantage, single female-headed households and residentially stable areas were associated with child pedestrian mortality. The study findings highlight the



need for critical action in terms of investment in child pedestrian safety research, and appropriate prevention initiatives guided by stringent evidenced-based studies, and the design of safe pedestrian, vehicular and urban environments.

**Keywords:** pedestrian mortality; children; South Africa; epidemiology; neighbourhood characteristics; urban environment

## **CHAPTER ONE**

### **BACKGROUND, RATIONALE AND SCOPE**

*All causes of death are equal in as much as they cause death. But some are less equal than others by being more overlooked, more taken for granted or more accepted as an inevitable part of life than others, which is scandalizing. Road traffic injuries must be counted among the less equal (Borowy, 2013).*

#### **1. INTRODUCTION**

Road traffic injuries (RTIs) constitute both a public health challenge, and a major cause of morbidity and mortality globally, but especially in the low and middle income countries (LMICs). Pedestrian injuries account for more childhood disabilities and deaths than any other causes of childhood injuries, traffic and non-traffic (World Health Organisation-WHO, 2008). The WHO Global Status Report on Road Safety (WHO, 2013b) indicates that, worldwide, the total number of road traffic deaths remains unacceptably high. In 2002 it was estimated that, globally, 1.2 million people were killed, and over 50 million people, including 300, 000 children, injured as a result of traffic crashes. In addition, 90% of the 1.2 million traffic related deaths, and 90% of the disability adjusted life years lost was as a result of road traffic injuries in LMICs (WHO, 2004).

The WHO Global Burden of Disease Update (2004) report indicated that approximately 950 000 children under the age of 18 years died of an injury, with the majority of these injuries resulting from road traffic collisions, but also including deaths due to drowning, burns (fire or

scalds), falls or poisoning. These five categories of injuries constituted up to 60% of all child injury deaths (WHO, 2004). Moreover, the report also indicated that the burden of these injuries, irrespective of cause, was uneven, as overall, more than 95% of all injury deaths in children occurred in the LMICs, and within these countries, poor children were disproportionately affected.

Although the child injury mortality rate is significantly lower among children from high-income countries (HICs), injuries remain a major cause of mortality, resulting in about 40% of all child deaths. Despite significant reductions in child pedestrian injuries and deaths in many of the high income countries, the prevention of such injury remains a problem, particularly among children ages between 5 and 14 years old. Among children aged 0 to 4 years and 5 to 14 years, the number of fatalities per 100 000 population in the low income countries was approximately six times greater than in the high income countries in 1998. As pedestrians, but also as passengers in buses and minibuses, and cyclists, the highest burden of injuries and fatalities is borne disproportionately by poor people in the developing countries. Some of the most vulnerable groups include those who live in chronic poverty, in remote rural areas, or in conflict zones or who have been displaced (Hulme, 2003; Hyder & Peden, 2002; Nantulya & Reich, 2002).

The Global Burden of Disease Report estimates that road traffic injuries will be the eighth leading cause of death globally in 2020, with an impact similar to that caused by many communicable diseases, such as malaria (WHO, 2013b). The patterns of both fatal and non-fatal traffic injuries vary by region, country, socio-economic status, age, sex, and road user type.

In 2010, the WHO African Region had the highest rate of road traffic deaths globally at more than 32 deaths per 100 000 population annually, as compared to the global rate of 18.0 deaths per 100 000 population (WHO, 2010). Almost 20% of all global road traffic deaths, a total of 234 768, occurred in the African Region, which also had less than 2% of the world's registered vehicles (WHO, 2009b). In an extensive review on road traffic injury studies in LMICs, Odero, Garner, and Zwi (1997) considered 31 studies that included data on population and vehicle-based rates. It emerged from 13 studies which had been conducted in Africa that, in 1989, South Africa had the highest reported population-based mortality rate of 35.8 deaths per 100 000 population followed by Swaziland with 28.0 deaths per 100 000 population in 1985.

A more recent road safety report on the WHO African Regions (2013a) indicated that, although the African Region continued to be the least motorised of the six world regions, it suffered the highest rates of road traffic mortalities, with 37 of the 44 surveyed countries having death rates well above the global average of 18.0 deaths per 100 000 population. As regards the 19 countries in the middle-income category, covering 44% of the African region's population, the rate was higher than the global average at 27.8 deaths per 100 000 population. By comparison, the global average for middle income countries is 20.1 deaths per 100 000 population.

Nigeria and South Africa have the highest mortality rates (33.7 and 31.9 deaths per 100 000 of the population per year, respectively) in the region (WHO, 2009b). More than one in four deaths in the African Region occur on Nigeria's roads, with six other countries; namely, Democratic Republic of Congo (DRC), Ethiopia, Kenya, South Africa, Tanzania, and Uganda, being responsible for 64% of all road deaths in the region. Ethiopia, Kenya, and Tanzania have relatively low road mortality rates for the region, as opposed to Nigeria, South Africa and Uganda which have extremely high mortality rates and large numbers of road deaths (WHO,

2009b). There are significant variations in traffic mortality across the African countries. For example, in 2010 the percentage of pedestrian mortalities on the roads in Mozambique was 55% and in Liberia 66.3%, while pedestrian injury estimates ranged between 39% in Tanzania and 75% in Cote d'Ivoire (WHO, 2013b).

Globally, 21% of all road traffic deaths were among children in 2004 (WHO, 2004). In the African region, vulnerable road users, including pedestrians, cyclists and motorised two and three-wheelers constituted more than half (52%) of traffic mortality with pedestrians alone comprising 37% of traffic mortality. Child pedestrian injury death is highest in the African and Eastern Mediterranean Regions (WHO, 2004).

The African continent's road traffic death rate for children exceeds the global rate of 10.7/100 000 population at 19.9/100 000 population (WHO, 2008). Despite the inter-country variations, studies indicate that pedestrians in general account for a major proportion of all traffic-related injuries and mortalities (WHO, 2013a). The global economic costs as a result of road traffic injuries are estimated at \$518 billion, with the LMICs in general incurring costs of approximately \$65 billion. This, in turn, translates to between 1 and 3% of a country's gross national product, more than the total amount received in development assistance. (WHO, 2009a; Roberts, 2007). It is clear that road traffic injuries may spiral dramatically if governments do not intervene expeditiously to prevent further road traffic injuries and mortalities (WHO, 2004).

## **2. SOUTH AFRICAN PERSPECTIVE**

There are approximately one million traffic crashes a year in South Africa. Compared to global trends, the death toll on South African roads is extremely high. Theron (2000) reports that, at

approximately 11 deaths per 100 million kilometres travelled, South Africa's traffic death rate is eclipsed only by that of Korea, Kenya and Morocco, while it is marginally higher than that in Brazil and Chile. The Road Traffic Management Corporation (RTMC, 2011) in South Africa reported approximately 40 deaths per day and 15 000 deaths annually. South Africa's road traffic death rate far exceeds the global middle income country mortality rate of 18.01 per 100 000 (WHO, 2013a). In fact, South Africa was recently ranked by the International Transport Forum's (ITF), (2012) latest road safety annual report as the worst, out of 36 countries, when it came to the number of road mortalities (Steyn, 2013).

This report is an issue of national concern for South Africa, and demands a cogent response. Road mortalities per 100 000 inhabitants stood at 27.6 deaths in 2011, a shocking statistic when compared to HICs in North America with 10.4 deaths per 100 000 inhabitants, or Australia with 5.6 per 100 000 inhabitants. The road mortalities for the low income countries (LICs) included in the report also did not exceed South Africa's road death toll, with approximately 12 mortalities per 100 000 inhabitants being reported in both Argentina and Colombia and 23.8 per 100 00 inhabitants in Malaysia (second worst). The report included provisional data that showed that, in South Africa from 1990 until 2011, the number of mortalities increased by 25%. Nevertheless, although the motorised fleet in the country has doubled in the last 20 years, fatal crashes decreased from 14 000 in 2011 to 12 200 in 2012. Pedestrians are particularly at risk and represented more than 35% of all the reported mortalities in 2012 (ITF, 2012).

South Africa's traffic mortality rate comprises mainly pedestrians, with children and adolescents as the significantly affected groups (NIMSS, 2013; Sukhai, Jones, & Haynes, 2009). The NIMSS contains South African pedestrian mortality data that reflects that the 15 to 45 years age group is the highest risk group, followed by the 0 to 14 years age group (NIMSS,

2013). This thesis focuses on the latter group as there is a lack of African and national studies on child pedestrian fatal injuries. There is also a dearth of studies that compare child fatal pedestrian injuries in relation to both motor vehicle passenger mortality, and of non-traffic, unintentional injuries such as burns and drowning. Children in the 0 to 14-year age group may be vulnerable to multiple injury types, because of their more limited developmental milestones and associated behavioural responses, including their more limited cognitive competencies to make decisions responsive to complex and precarious road traffic environments.

This doctoral thesis aligns itself with the conventions adopted by the WHO and other international and South African child injury research, such as the NIMSS, and uses categories for children aged 0 to 14 years for conducting analyses on childhood pedestrian deaths. Childhood pedestrian fatal injuries are concentrated in the 5 to 9-year age group, followed by the 10 to 14-year-old, and then the 0 to 4-year age groups (Matzopoulos, 2004). In its recent road traffic report of 2011, the Road Traffic Management Corporation (RTMC), which is the leading agency in the National Department of Transport (NDOT) of South Africa, released the following salient information. The percentage of all childhood mortalities in the 0 to 14 year age group and sex in the population was indicated as follows: in children 0 to 4 years old, there was 3.34% male and 1.65% female motor vehicle passengers as compared to 4.37% males and 2.96% female pedestrians while, in the 5 to 9 year old age group, there was 2.31% males and 1.46% female motor vehicle passengers as compared to 6% males and 3.60% female pedestrians, and, lastly, among the 10 to 14 year olds, there was 2.23% male and 1.97% female motor vehicle passengers as compared to 3.26% male and 1.39% female pedestrians.

Male pedestrians in all age groups reflected higher percentages as compared to females, both as motor vehicle passengers and as pedestrians. Du Toit and Bass (2000) highlighted that RTIs

constituted the single most important cause of injury-related death and disability in South African children over four years of age, with pedestrian injuries accounting for 46% of all casualties in this group, and 25% of the potential life lost (Du Toit & Bass, 2000).

Further available statistics indicated that, during 1997, 633 child pedestrians were killed in South Africa, i.e. translating into more than one child each day. A total 5769 children were injured non-fatally, with children of school-going age at the highest risk, especially from age five onwards, and of which, 46% were child pedestrian deaths and injuries in the 5 to 9-year age group. The majority (58%) of these mortalities occurred when children were crossing the road, i.e. either at an ordinary traffic crossing, a dedicated pedestrian crossing or elsewhere, but with most of the mortalities occurring away from crossings. The main reason for mortality in children aged less than 8 years of age has been cited as their lack of experience and maturity as regards coping with and managing the traffic system and road environment in South Africa (Du Toit & Bass, 2000). Pedestrian studies conducted in South Africa concur that the overall pedestrian mortality remains high, especially among the 5 to 9 year olds (Donson, 2005; Matzopolous, 2004; Mabunda, Swart, & Seedat, 2008; Sukhai, 2003). Their findings are also in agreement with those of the global studies alluded to earlier (WHO, 2008).

Road crashes cost the South African economy R133 billion in 2011 (Road Traffic Management Corporation (RTMC, 2011). This economic cost is a significant drain on the development trajectory of a country faced with lags in areas such as health, education, housing, job creation and water and electricity production (RTMC, 2011). A recent International Transport Forum (ITF) (2012) report documented that the estimated economic cost of South Africa's road crashes had drastically increased to R307 billion (Steyn, 2013).



Despite the implementation of road safety campaigns on a national scale, it would appear that South Africa has not been able to achieve a substantial reduction in the number of pedestrian non-fatal injuries and mortalities (RTMC, 2011). In the provinces of Limpopo and Free State, road crashes increased by 9% and in KwaZulu-Natal by more than 7% between 2008 and 2009 (RTMC, 2011). It would seem that road traffic safety in South Africa is partially compromised by inadequate legislation and enforcement, insufficient protection of pedestrians and cyclists, excessive driver and pedestrian alcohol consumption, speeding, uneven law enforcement, poor pedestrian environments and infrastructure, inadequate post-accident care, and dangerous driver and pedestrian road behaviour (Ribbens, Everitt, & Noah, 2008; RTMC, 2011).

The absence of both innovative approaches and robust evidence-based and quality assured data systems in traffic injury research is compromising the intervention efforts in respect of safety promotion, which is, in turn, among the most complex public health and societal problems the country faces (Rivara, 2002). Pedestrian injury prevention highlights the need to design better indicators of risks, and also to develop new methods for understanding and assessing safety in order to complement those existent in the road accident statistics (Hillman, 1993; Laflamme & Diderichsen, 2000; Rivara, 2002; Shrinivasan, O'Fallon, & Dearry, 2003).

While there has been a steady increase in the empirical response to traffic injury mortality in the LMICs, the work on childhood pedestrian mortality prevention is still in its infancy in South Africa. This is evident in the intermittent research in South Africa that is focused on child pedestrian injuries (Butchart, Kruger, & Lekoba, 2000; Du Toit & Bass, 2000; Mabunda et al., 2008; Matzopolous, 2004; Sukhai, 2003; Venter, 2000; Swart, Laher, Seedat, & Gantchev, 2014). There is clearly a need to develop our understanding of the epidemiology, risks and typologies underlying childhood pedestrian injuries and mortality, particularly in view of the

fact that, since the mid-1990s, there has been an absence of comprehensive epidemiological and ecological studies on fatal pedestrian injuries that go beyond descriptive quantitative analysis.

It is anticipated that this doctoral thesis will address this gap in the research. The study seeks to strengthen the existing empirical base by incorporating quantitative analytical research methods in order to examine the following: pedestrian mortality trends over time from 2001 to 2010, the circumstances of pedestrian mortality as compared to other traffic mortality, specifically motor vehicle passenger mortality, and non-traffic mortality, specifically burns and drowning; and the individual and compositional effects of neighbourhood determinants on child pedestrian mortality.

### **3. RESEARCH FOCUS AND AIMS**

The main aim of this thesis was to advance our insight into the contributory factors associated with childhood pedestrian mortality in South Africa, and to complement the existing evidence base that informs the development, promotion and implementation of prevention initiatives. This doctoral thesis considers the complexity of the phenomenon of childhood pedestrian behaviour and, the pronounced vulnerability of children and pedestrian deaths in children aged 0 to 14 years. Child pedestrian mortality is the leading cause of unintentional injury when compared to children as motor vehicle passengers, and in relation to non-traffic deaths, such as burns and drowning, which occur predominantly in context specific environments.

In addition, there is a dearth of studies in the last decade on child pedestrian deaths in relation to other traffic and non-traffic deaths in Johannesburg, South Africa. Since NIMSS has full coverage of fatal child unintentional injuries for Johannesburg from 2001 onwards, this

doctoral thesis aspires to provide new and comprehensive empirical evidence and trend analysis over a ten year period, by focusing on several objectives which contextualise the multifaceted interplay of the individual and neighbourhood factors that are associated with fatal child pedestrian injuries in relation to children as motor vehicle passengers, burns and drowning within an ecological systems model, in Johannesburg for the period 2001 to 2010. The doctoral thesis intends to achieve the following objectives:

- To describe the incidence, demographics and circumstances of childhood pedestrian mortality in Johannesburg (2001–2010)
- To identify the demographic and circumstantial risks that differentiate childhood pedestrian mortality from childhood motor vehicle passenger mortality in Johannesburg (2001–2010)
- To identify the demographic and circumstantial risks that differentiate childhood pedestrian mortality from childhood burns and drowning mortality in Johannesburg (2001–2010)
- To identify neighbourhood-level predictors of childhood pedestrian mortality in Johannesburg (2001–2010)

#### **4. STRUCTURE AND ORGANISATION OF THE THESIS**

This thesis comprises seven chapters including the introductory chapter. Chapter Two, which is entitled ‘Childhood pedestrian injuries: epidemiology and risk factors’, provides a broad overview of the aetiology of childhood pedestrian injuries in terms of individual, familial and community risk factors, including poverty and the effects of urbanisation and motorisation within the context of globalisation. Chapter Three is titled ‘Theoretical perspectives on the distribution and aetiology of childhood injury’ provides a perspective on injury causation.

Chapter Four, entitled ‘Research design’, presents a detailed overview of the methods used in order to realise each of the four research objectives while Chapter Five, ‘Results’, systematically explains the research findings. Chapter Six (Discussion) discusses the main research findings in a critical and coherent manner. Finally, Chapter Seven (Conclusion) presents a synopsis of the main findings which emerged from the study. This is followed by recommendations for future research, limitations of the research study, implications of the findings for childhood pedestrian injury prevention, and the study’s contribution to research. The next chapter contains a comprehensive overview of the aetiology of childhood pedestrian injuries, and mortality, in terms of epidemiology (individual risks), and risk factors (contextual drivers).

## **CHAPTER TWO**

### **CHILDHOOD PEDESTRIAN MORTALITY: EPIDEMIOLOGY AND RISK FACTORS**

Road traffic crashes are among the 15 leading causes of the disability-adjusted life years (DALYs) for children aged 0 to 14 years (WHO, 2013a). There is a multiplicity of reasons why young children are vulnerable to RTIs. Identifying and understanding the risk factors that expose young children to the risk of a road traffic injury may contribute significantly to the prevention of such injuries. Several studies have considered the characteristics of the child as potentially powerful predictors of pedestrian injury and mortality. These include age, sex, social status and place of residence (Durkin, Araque, Lubman, & Barlow, 1999; Malek, Guyer, & Lescohier, 1990). A study by Morrengellio and Lasenby-Lesard (2007) highlights the importance of examining child, family and socio-environmental factors in order to understand both the exposure of children to injury as well as their individual vulnerability and risk-taking behaviours. The risks which are intrinsic to childhood increase children's vulnerability in traffic (WHO, 2008).

In the effort to attain the research objectives, this chapter will focus on the individual, familial, community and contextual risk factors associated with the epidemiology of childhood pedestrian injuries and mortality within a global, African and national context. The chapter concludes by highlighting the need to address the existing gaps prevalent in current childhood pedestrian research initiatives in South Africa.

## **1. INDIVIDUAL FACTORS**

### **1.1 Age and Development**

The disparate risk of children to pedestrian injury may be attributed to several factors. Studies have revealed that, overall, children's exposure to risk and injury is predicated by their age, physical, cognitive and perceptual capacities and skills when negotiating traffic (Assaily, 1997; Demetre, 1997; Lak, Hajari, & Naderi Beni, 2014; Rivara, 1990, 1995). Evidence has also identified a child's age as a major determinant in terms of mobility and independence. Similarly, the child's skills and responses are also age dependent (Schieber & Vegega, 2002). It is understandable that children aged between 1 and 4 years are highly susceptible to risk because of their diminutive size and minimal traffic experience, and, hence, they may easily sustain injuries. According to some studies, younger elementary school children (aged 5–9 years) are the most vulnerable to pedestrian injuries because their knowledge as well as their cognitive and perceptual skills are not yet fully developed (Agran, Winn, & Anderson, 1994; Sethi, Towner, & Vincenten, 2008).

Surveys conducted in five Asian countries highlighted road traffic injuries as the second leading cause of child mortality support this notion of vulnerability (Kumar & Ross, 2006; Rahman, 2005; Sitthi-Amorn, 2006). Similarly, studies in Africa in Kampala, Uganda and in Ghana identified road traffic injuries as by far the most common cause of both morbidity and mortality for all ages, except those younger than five years but with school-aged children comprising the majority of victims of road traffic crashes (Hsia, Ozgediz, Mutto, Jayaraman, Kyamanywa, & Kobusingye, 2011; Kumar & Ross, 2006; Mock, Abatanga, Cummings, & Koepsell, 1997). The findings of studies conducted in South Africa are in line with global trends (Norman, Matzopolous, Groenewald, & Bradshaw, 2007).

As children mature into preadolescents and young adolescents between the ages of 10 and 14 years, they acquire more traffic experience, and also gain in confidence, become independent, require less supervision, begin to travel further from home, and tend to become more decisive and, as a result, they may engage in risky pedestrian behaviour. Evidence indicates that youth are injured on relatively busy streets further from home because of their increased mobility (Agran et al., 1994).

## **1.2 Sex**

The majority of studies on road traffic injuries show evidence of a strong relationship between sex, road safety behaviour and road traffic injury. In most regions worldwide, the difference in sex for fatal injuries increases with age, with at least twice as many boys being killed in road traffic crashes as compared to girls. This also applies to fatal and non-fatal injuries (Lak et al., 2014; LaFlamme & Diderichsen, 2000; Safe Kids, 2006; Sethi, Towner, & Vincenten, 2008; Stevenson, Jamrozik, & Burton, 1996; Towner, Dowswell, Errington, Burkes, & Towner 2005; WHO, 2008).

This global age and sex mortality rate, as reflected among children under the age of 1 year as well as those aged 1 to 4 years, is the same for males and females. However, in children aged 5 to 9 years old, the male death rates are a third higher than the female death rates, with an inconsistency of approximately 60% among children aged between 10 and 14 years old (WHO, 2008). The findings of African studies concur with those of the above international studies (Amo & Meirmanov, 2014; Nakitto, Howard, Lett, & Mutto, 2008; Mock, Abantanga, Cummings, & Koepsell, 1997). Conversely, a study conducted in Nigeria indicated that the female mortality rate was worse despite similar exposure and injury severity as compared to the male mortality rate. However, this was explained on the basis of a cultural tendency to send

girls out on errands instead of boys (Berger & Mohan, 1996; Solagberu et al., 2014). In general, however, boys are more likely than girls to be injured although this may be due to greater differences in their exposure to traffic rather than to any intrinsic factor. Similar findings were reflected in South African studies (Donson, 2005; Burrows, Van Niekerk, & Laflamme, 2010; Matzopolous, 2004; Pretorius & Van Niekerk, 2014; Swart et al., 2014; Sukhai, 2003).

Using an anthropological perspective, Schieber and Vegega (2002) suggest that a cautionary approach must be adopted when conveying messages such as boys do not need to be as careful as girls, or that boys should be supervised less closely than girls. Assaily (1997) supports this suggestion. Such messages may have unintended consequences, as issues of social construction are theoretically amenable to educational and social change, whereas biologic differences are immutable. Despite studies having repeatedly reported the increased risk for boys, few studies have directly addressed this sex difference in their interventions. This may be perceived as a weakened response to targeting the most vulnerable road users, and does merit further consideration (Towner, Dowswell, Errington, Burkes, & Towner, 2005).

### **1.3 Physical Stature**

When considering additional individual factors in childhood pedestrian injuries, Christoffel, Donovan, Schofer, Wills and Lavigne (1996) focused attention to the role of bio-psychosocial attributes. These attributes include the cognitive (i.e. awareness of hazards), perceptual (i.e. undeveloped strategy in traffic), emotional, gross motor (coordination), judgemental and social skills. These traits, combined with the physical stature (weight, height) and agility of the child, independently affect the child's ability to respond and be visible in traffic (Sethi et al., 2008). Studies also suggested that the over-involvement of younger children in pedestrian injuries may be a consequence of parents / caregivers permitting their children to use roads alone at a



time when they lack the maturity required for adapting to traffic environments, and to also include children with severe vulnerabilities and physical disabilities who may require an individual approach to injury prevention (Christoffel et al., 1996; Hillman 1993; Schieber & Vegega, 2002; Towner et al., 2005). African and South African studies also single out these bio-psychosocial attributes in children (Nakitto, Howard, Lett, & Mutto, 2008; Munro et al., 2005).

#### **1.4 Behaviour**

Although the role of behaviour in injury risk has not been analysed in detail, Schieber and Vegega (2002) intimate that the way in which an individual behaves prior to the event may be predicated by the child's emotional state. Researchers in the United Kingdom investigated the perceptuo-motor and cognitive development and abilities of children in traffic contexts and also evaluated training programmes aimed at enhancing these abilities. These programmes focus on a child's ability to be vigilant, interpret traffic signs, remember simple rules, locate sounds, judge speed and attend to objects in the peripheral vision. While it has been established that individual factors such as age and physical developmental level significantly affect risk, emotional instability also appeared to be a causal factor in some cases (Du Toit & Bass, 2000; Munro et al., 2005; Nakitto et al., 2008). However, whether such differences in behaviour are due to developmental differences and socialisation, pedestrian behaviour or differences in exposure requires further exploration.

## **2. FAMILIAL AND RELATIONSHIP DYNAMICS**

In view of the fact that young children are particularly vulnerable by virtue of their developmental phase, it is vital that parents are actively involved in injury prevention. Researchers have suggested that parents often overestimate their children's developmental

skills, and have inappropriate perceptions of their developmental abilities. In other words, a child's skills may not be at the level required for the safe completion of many tasks, thereby creating an opportunity for injury (Morrongiello, 2005; Munro et al., 2005; Rivara, 1995). It may be that this finding signifies a trend that helps to explain the increasing prevalence of injury rates as children become older, and with the concomitant parenting shifts to accommodate the more independent stages of growth and development, and the resultant increased risk behaviour. Beth, Lake, Eden and Denney (2004) proposed that sensitivity should be accorded to parents as they are exposed to the challenges arising from achieving a balance between enhancing development and minimising risk. In addition, there is also a complex interaction between the child's physical health, social competence and risk-taking behaviour. Approaches to supervision should change with various combinations of these states (Morrongiello, 2005). Thus, caregivers need to be aware of this, and adjust their supervisory levels accordingly.

The family environment contributes significantly to the emotional influence on the child. This influence extends to other settings such as the extended family, early child care, education, neighbourhood and playground. The quality and quantity of the experiential processes that the child undergoes with the people and objects in these settings (e.g. the child's family and preschool) together with external factors (e.g. community or government laws) all contribute to the child's development. The supervision of children has, thus, also been examined as a predictor of injury rates. However, the focus of research has been mainly on either parental or child factors but with very little of the research examining a combination of these factors (Kisida, Shandor Miles, Holditch-Davis, & Carlson, 2001; Landen, Bauer, & Kohn, 2003; Munro et al., 2005; Saluja, Brenner, Morrongiello, Haynie, Rivera, & Cheng, 2004).

A study comparing the supervision beliefs and practices of mothers and fathers revealed that maternal supervision tends to have a greater impact than paternal supervision, simply because mothers usually spend more time with the children than the fathers (Morrongiello, Walpole, & McArthur, 2009). Morrongiello (2005) suggested that a thorough appreciation of combinations of factors is critical in developing preventative interventions aimed at those children who are at risk of unintentional injury. However, significantly more information is required to understand the relationship between the factors influencing parental perceptions of injury, prevention beliefs, and the social influence on these beliefs, and parental preventative behaviours. It is widely acknowledged that supervision plays a central role in protecting children from harm.

Statistics suggest that 90% of injuries to young children occur in or around their homes when they are supposedly being supervised by a caregiver. Instead, there is limited evidence attesting to the fact that childhood injury is often related to a lack of supervision. The following is a formal definition of the term “supervision” in the context of injury prevention, namely, that supervision refers to behaviours that are related to *attention* (watching and listening) and to *proximity* (touching, or being within reach). Furthermore, these behaviours are judged by how *continuous* they are (whether constant, intermittent or not at all) (Morrongiello, 2005). Research has shown that there is no generally agreed upon supervisory style, and therefore it is critical to evaluate the various supervision strategies, and measure their impact on reducing injuries (WHO, 2008).

Surveys carried out in Europe suggest that parents often have unrealistic expectations of their children’s pedestrian skills. The emphasis of these studies is on the roles of parents and teachers, and the psychological processes underlying imitation, identification and the affective

relationship between child and parents (Munro et al., 2005; Schieber & Vegega, 2002). A study conducted in England by Foot, Tolmie, Thomson, McLaren, & Whelan (1999) revealed that the majority of parents, teachers, and police officers place the blame and the responsibility for pedestrian injuries on children. It is essential that parents are aware of the different levels of a child's development.

It is worth noting that cultural and political environments also influence the way in which children are socialised in terms of developing coping skills. Caregivers may permit boys to spend more time outdoors unaccompanied by adults as compared to girls, with their attitudes and practices related to male independence being used to justify such actions (Assailly, 1997). The family is the primary social group through which a child is initially introduced to social mores, norms, and conventions, and therefore, it contributes to the child developing the necessary coping skills, including those linked to safety.

### **3. COMMUNITY AS SOCIAL AND PHYSICAL ENVIRONMENTS**

The role of sociology in childhood pedestrian injuries is receiving increasing attention in literature. Schieber and Vegega (2002) allude to a social paradigm within the context of pedestrian injuries as an interaction between social factors in the environment. The literature focuses on factors such as family, socio-economic status (SES), place of residence and type of housing, poverty, highest level of parental education achieved, supervision of children, degree of dependence on walking for the purposes of transportation, availability of recreational space and the design and maintenance of roads as possible factors which are likely to contribute to child vulnerability (Assailly, 1997). Some of these factors are expanded upon below.

Several studies consider the characteristics of the child as a potentially powerful predictor of pedestrian injury. These characteristics include age, sex, social status and place of residence (Durkin et al., 1999; Malek, et al., 1990). Research on risk taking in children is limited, although a study conducted by Morrengellio and Lasenby-Lesard (2007) highlights the importance of examining child, family and socio-environmental factors in order to understand the risk-taking behaviours of children. Rivara, (1990) also posits that in areas of low socioeconomic status, there is an increased risk of children's exposure to pedestrian injury because of an inadequate availability and accessibility to recreational facilities and schools / crèches, compounded by high traffic volumes and density, higher average and posted speed limits, fewer pedestrian control devices, and less well maintained streets, including fewer alternatives to the street for play.

### **3.1 Physical Environment**

Several studies in the literature document a direct link between the physical environment and risk of pedestrian injury. This link is unfortunately more prominent in highly urbanised, low-income communities where children are more prone to injuries, particularly near or outside their homes in a residential street, in the late afternoon or early evening, and during peak holiday seasons. Also, when darting out into the street mid-block, dashes across intersections, alighting from buses, or the immediate vicinity of a bus stop. The lack of recreational parks and safe play areas, including poorly maintained roads or other hazardous walking or driving conditions and crowded housing. All of these factors contribute to the frequency of pedestrian injuries (Braddock, Lapidus, Cromley, Burke, & Banco, 1994; Dougherty, Pless, & Wilkins, 1990; Henson & Petch, 2000; Morrongiello, & Lasenby-Lesard, 2007; Rivara & Barber, 1985). Parked cars, high traffic volumes, and curb-side parking are also significant predictors of injury

(Agran et al., 1994; Rivara, 1990; Roberts, Norton, Jackson, Dunn, & Hassall, 1995; Stevenson, Jamrozik & Burton, 1996).

In view of the fact that roadways and neighbourhoods do not belong exclusively to adult drivers, but also to the children who live there. Both citizen participation, and political will are necessary to ensure that, instead of restricting the type and range of children's physical activities, community and environmental remodelling render communities more conducive for children to walk. This is possible when neighbourhoods advocate for legislation to direct a portion of government transportation funds to be expended on safe pedestrian and bicycle routes to schools (Killingsworth & Schmid, 2001).

### **3.2 Social Environment**

A social paradigm exists in which pedestrian injuries and deaths result from social factors which interact in a dangerous environment. However, few studies have examined the role of the social environment on walking and driving behaviour. Putnam (1993) posits that social capital can enable co-operation and mutually supportive relations in communities and nations, and therefore be a valuable means of combating many of the social disorders inherent in modern societies, for example crime. He further mentions that social capital can be broadly conceived as those characteristics of social organisation such as networks, norms of reciprocity, and trust in others to facilitate cooperation between citizens for mutual their benefit (Putnam, 1993). The term "collective efficacy", encompasses the social cohesion of the neighbourhood and its residents as a "willingness to intervene for the common good". These terms have found widespread applicability when describing the social environment (Sampson, Raudenbush, & Earls, 1997, pp. 919).

Runyan (2003) suggests that social norms, cues and pressures may explain the higher pedestrian injury rates in low income neighbourhoods. Such norms may include different expectations of behaviour, or different requirements for safety either from individual households as well as the values of neighbours. Accordingly, it may be regarded as normal in some neighbourhoods for children to play in the street, play outside when it is dark, or encouraged by their parents to walk to school, while in some areas, parents may not allow such behaviour. Nevertheless, in many, if not most South African communities, there is an absence of safe pedestrian environments.

Leyden's (2003), study was premised on whether the way in which communities and neighbourhoods are designed and built either enables or discourages social ties or community connectedness. Traditional neighbourhoods were designed to encourage walking, and pedestrians were not required to compete with cars along busy highways, or to walk across sprawling parking lots. Many of these neighbourhoods had amenities such as shops and places of worship within walking distance. However, because of suburbanisation, if the residents of a community want to shop, worship, or go to a park or library, they are often forced to travel by car. Citizens are, thus compelled to drive to find recreational spaces. Theoretically, pedestrian-oriented, mixed-use neighbourhoods are expected to enhance social capital because they enable residents to interact either spontaneously or casually. However, the majority of contemporary suburban neighbourhoods do not to promote social interaction (Leyden, 2003).

The Centres for Disease Control and Prevention (CDC) (2002) have discovered that, instead of walking or biking to school, most children now use buses or are driven in private vehicles, with the main deterrents to walking or biking, including long distances (55%) and traffic danger (40%).

Leyden (2003) further suggests that government policy could help change our concept of the built environment, by discouraging sprawl and encouraging the creation of new pedestrian oriented towns and neighbourhoods. In addition, neighbourhoods which are designed to encourage walking may enable social capital, and also enhance a sense of community among the residents (Wood, Frank, & Giles-Corti, 2010; Kim & Kaplan, 2004; Leyden, 2003; Lund, 2002).

Although researchers have demonstrated a relationship between child behaviour characteristics and pedestrian injury rates, other studies have focused on family characteristics such as the relationships between parental or family stress, parental beliefs and emotions, single parenthood, low maternal education, low maternal age at birth, poor housing, large family size, parental drug and alcohol abuse, parental attitudes and preventative behaviour, and the presence or absence of social supports in relation to childhood injury (Beth et al., 2004).

Durkin et al. (1999) suggests that limited extracurricular activities, and the lack of access to affordable childcare, are also potential factors in the high rates of pedestrian injury in low income neighbourhoods. Runyan (2003) also suggests that differences in recreational activities, which could be related to the lack of absence of after school programmes, may play a role in the increased injury risk in low - income neighbourhoods. If the high cost or limited availability of after school programmes prevents children from enrolling either in such programmes or in childcare, they may be more likely to play on public streets and pavements and this, in turn, could lead to higher rates of injury, especially when combined with the physical environment and lack of supervision.



A family's socio-economic status often determines the choice of neighbourhood, type and design of the housing unit, degree of dependence on walking for transportation, existence of fenced in yards, availability and characteristics of recreational spaces, internal roads as well as the amount and availability of supervision when the child is at play (Schieber & Vegega, 2002).

The stability of a neighbourhood affects the ability of its residents to develop the social capital, collective efficacy, and a sense of community (Putnam, 1993; Sampson et al., 1997) which, if evident, may help to prevent childhood pedestrian injury and death. In their review of social differences in childhood traffic injury risks, Laflamme and Diderichsen (2000) concluded that these mechanisms remain poorly understood, and require interrogation and further research.

#### **4. POVERTY**

Poverty or socio-economic background is one critical aspect of injury prevention research which had not been given the prominence it merits (Jackson, 1997). Laflamme and Diderichsen (2000) highlighted that inequity is more pronounced in the younger age groups, and that although RTIs are prominent among children, adolescents and young adults, it is also considered to be a cause of mortality that is associated with people in the highest social inequality class gradient. Durkin et al., (1999) refers to studies that demonstrated a greater incidence of road injuries and deaths involving children from disadvantaged backgrounds, although precisely how this unfolds is uncertain. Nevertheless, poverty remains a significant predictor for severe childhood injury and mortality.

In their review of the literature White, Raeside, and Barker (2000) documented that the risk of death for child pedestrians is related to socio-economic class, parental circumstances and ethnicity. Their study also revealed that the children from the lowest SES are four times more

likely to be killed on the road compared to those from the highest SES. Similar findings were also confirmed in a previous study conducted by Roberts, Norton and Taua, (1996). An earlier study by Christie (1995a) suggested several reasons for the prevalence of pedestrian injuries in the lower socio- economic status neighbourhoods. These included the following: children from disadvantaged backgrounds are at greater risk due to higher exposure rates (fewer parents own cars) and, they have less adult supervision in the traffic environment with educational disadvantage playing a role in understanding issues of road safety and the psychological state of the child. In addition, deprived children often exhibited different behavioural patterns that increased their susceptibility to road traffic crashes.

However, the ability to develop reliable estimates of injury risk is constrained by limited data on walking rates among specific demographic subgroups, incomplete records of pedestrian injuries, and the lack of a consistent measurement tool of injury. In addition, children's travel patterns and needs have been in transportation research (Dougherty et al., 1990; Johnson, Geyer, Rai, & Ragland, 2004).

Although it has not yet been thoroughly investigated, there is also a strong relationship between SES and vehicle ownership rates. This is also directly linked to the incidence of walking trips in low SES households. Cars have definite benefits for children, with poor children being more likely to be killed or injured in road crashes as compared to those from affluent homes. For example, it has been shown that the lack of access to a car increases pedestrian injury risk twofold (Johnson et al., 2004). Jackson (1997) highlights the increasing trends of inequality between affluent families and poorer families in the United Kingdom, and undoubtedly elsewhere. South Africa is faced with the triple threat of poverty, unemployment and

inequality. If and when this triple threat is addressed, it may be possible to envisage a substantial decline in the child pedestrian injury rate (Jackson, 1997; Nicolson, 2015).

## **5. URBANISATION AND MOTORISATION**

### **5.1 Urbanisation**

A further imperative that merits investigation is the ubiquitous impact of urbanisation and motorisation on childhood pedestrian injury within the context of globalisation. Currently, more people (50.5% of the world's population) now reside in urban as opposed to rural areas (United Nations, 2011). Although it would appear that the rate of the urban population is showing a decline, it continued to remain extremely high on the African continent for the period 2005 to 2010. This may be attributable to both rural migration and a natural increase in birth rates in the population (Berger & Mohan, 1996; United Nations, 2011). A major challenge confronting both current and future urbanisation stems from the reality that, essentially, increasing urbanisation will occur in the LICs which are characterised by poverty (United Nations, 2011).

Urbanisation is a disquieting phenomenon when it is unplanned and badly resourced, which in turn, exacerbates children's exposure to risk. Urban slums and 'informal settlements' pose high risks of injury for children throughout the world (Chaplin, 1999; Dandona, Kumar, Ameer, Ahmed, & Dandona, 2008; Lawrence, 2012; Gracey, 2002; McMichael, 2000, Reichenheim & Harpham, 1989; Rizvi, Luby, Azam, & Rabbani, 2006). Berger and Mohan (1996) indicated that because of rural-urban migration, several cities are already not coping with providing essential services such as basic medical care, social services, potable water, sanitation, housing and employment, with these problems being compounded by the mass transition of vast

numbers of residents. Massive overcrowding and inadequate infrastructure contribute to traffic injuries, alcohol and drug addiction, mental challenges and violence.

The impact of this is felt mainly by the children. Half of the 1.3 billion children in LICs spend their entire lives in temporary shelters, while increasing numbers are abandoned by their disenfranchised and destitute parents. Urban poverty is rife, particularly among the multitudes of children and families. For example, approximately 14 million people in Brazil are living in abject conditions. In many LICs, informal dwellers represent 50 to 75% of the urban population, with the high population density in these areas exposing residents to precarious health and injury hazards (Berger & Mohan, 1996). In addition, industrialisation both in rural and urban settings has contributed to a sizeable increase in the number and severity of injuries.

The proliferation of urban slums and squatter camps poses high risks of injury for children throughout the world (Ampofo-Boateng & Thomson, 1991; Pitcairn & Edlemann, 2002). Many African cities have to deal not only with the proliferation of slums, but also with increasing insecurity and crime. In South African cities, this is a worrying phenomenon, with two thirds of South Africa's population now living in urban areas. This number is also likely to increase to over 70% by 2030 (Potts, 2012). This trend may be attributed to post-apartheid, with the increasing movement of people from the 'homelands' (most of which were predominantly rural and with limited economic bases) to urban areas with higher economic growth. However, the main disadvantage of this is that it may fuel crime and social tensions, create greater environmental and health risks, and pose challenges to the government's service provision. The City of Johannesburg is under immense pressure as a result of an influx of people flocking to urban centres. Accordingly, the city is having to confront several issues, including a scarcity of suitable land for housing, and the existence of informal settlements (Crankshaw & Parnell,

2002; *SAinfo* Report, 2013). The number of people living in urban areas increased from 52% in 1990 to 62% in 2011, while those living in rural areas declined from 48% to 38% over the same period (StatsSA 2011).

It would appear that in general, in South African cities, because of the rapid urbanisation due to natural population growth and migration, injuries are concentrated in the low-income neighbourhoods which are characterised by a lack of infrastructure, resources, overcrowding and poverty (Butchart et al., Cohen, 2006; Peden, Oyegbite, Ozanne-Smith, Hyder, Branche, Fazlur Rahman, & Bartolomeos, 2008; South African Cities Network, 2011; Swart et al., 2014; Van Niekerk, Seedat, Bulbulia, & Kruger, 2001). The rapid urbanisation in the LICs in the coming decades will have profound implications for safety and health, underscoring the critical importance of the judicious management and governance of cities to reduce and eradicate poverty, as well as achieve the other developmental goals (United Nations, 2011).

## **5.2 Motorisation**

Motorisation refers to the influx of motor vehicles without concomitant changes in roads, pedestrian patterns, and or traffic enforcement capabilities (Berger & Mohan, 1996). As the global vehicle production increases, the roads have to be shared by a mix of users including pedestrians who remain unprotected and vulnerable. Currently, RTIs are a major public health burden, while their counterpart, motorisation, is a global public health issue that has profoundly important consequences for the health and safety of the population (Roberts, 2011). Approximately 3 000 people die on a daily basis, while 30 000 people are seriously injured on the world's roads in traffic crashes. More than 85% of these deaths occur in the LMICs, with pedestrians, cyclists and bus passengers bearing the brunt of this. Those who are fatally injured often do not own a car, and in fact, most of them are children (Roberts, 2011).

Roberts and Coggan (1994) related that the main determinants of injury risk were the volume and speed of traffic. They further mentioned that the injury risk increased exponentially with rising traffic volume, and that children living in the busiest streets were fifteen times more likely to be injured as compared to children living in the quieter streets. In addition, the risk of road death for a child from the lowest social group was five times that of a child in the highest social class (Edwards, Green, Roberts, Grundy, & Lachowycz, 2006).

Berger and Mohan (1996) also posited that increasing population growth and urbanisation also pose an additional challenge to the LICs as regards the manufacture of new vehicles with increased acceleration rates in the HICs. In LICs in particular, several factors contribute to the high rates of motor vehicle injuries. These include, the high proportion of children and youth in the populations, people and cars are not being separated, roads are used for informal business/vending, playing and walking, a mix of vehicles with varying speeds, and pedestrians, especially children. In addition, the recent migration to the cities of people who are unfamiliar with traffic behaviour, poor or non-existent road lighting, no road markings and signage, and the lack of or absence of law enforcement (Berger & Mohan, 1996).

More recently, studies have indicated that the rapid growth in vehicular traffic throughout the world is germane to issues such as the inequalities in road safety, climate change, congested roadways, quality of life in urban and rural areas, the devastation and depletion of natural resources, fewer green public spaces, reduced opportunities for movement, inequalities in social justice, and overall poor public health (Roberts, 2011; WHO, 2004).

There has also been research conducted into the association between RTIs and other socioeconomic indicators (Kopits & Cropper 2003; Grundy, Steinbach, Wilkinson, & Green,

2009). Previous studies included a World Bank report that revealed, as one of its principal findings, the existence of a positive relationship between GNP per capita, and an increase in road traffic mortality rates for 83 countries, with the poorest countries exhibiting the highest incidence of mortality rates (Grundy et al., 2009; WHO, 2008). These empirical results not only exposed the purported contribution of ‘economic development’ to mobility, but also pointed to increased motorisation and, ultimately, a higher exposure to risk. By 2020 road crashes will have moved from ninth to third place in the world ranking of the burden of disease and injury, and will occupy second place in LICs (Roberts, 2011; WHO, 2004;).

Despite the fact that the African region is the least motorised of the six world regions (2% only of the world’s vehicles), it would appear that it suffers the highest rates of road traffic mortalities, and contributes 16% to global deaths (WHO, 2009). Vehicle density is one of the major determinants of road traffic mortality, and is also closely related to income. Although it may be acknowledged that, in many countries, the number of officially registered vehicles may not be a realistic reflection of the actual number of vehicles on the roads, it may be assumed that some motorisation rates would still remain in the single digits. This highlights the extreme income disparities in these countries and, while a small proportion of the populace earns relatively high incomes, the number of vehicles accessible to the entire population remains relatively low (WHO, 2004). Motorisation rates in the African region range from 1 to 265 vehicles per 1000 population, with a median of 18 vehicles per 1000 population. This, in turn, translates into a very low motorisation rate in the majority of African countries. Conversely, the European Region has a median of 357 passenger cars per 1000 population; twenty times that of the African Region (WHO, 2004).

In South Africa, while the majority of the residents of Johannesburg do not own vehicles, the middle-income residents are extremely car-oriented. In January 2015, there were 1603106 motor vehicles in the City of Johannesburg, with an annual increase in traffic of 7%. The vehicle per population in Gauteng is 4 168 142, with an average increase of 0.18%. South Africa's total road network comprises approximately 747 000 km – the longest network of roads in any African country (Chakwizira, 2007; RTMC, 2011). The very low vehicle ownership rates have indicated that, for many countries, a sharp rise in motorisation would probably result in even higher mortality rates. Exposure to the risk of being involved in a road traffic accident is inevitable for the vast majority of road users who constantly share the roads with fast moving motorised vehicles.

In his analysis of the proposed road infrastructure programmes in African nations, Roberts (2011) illustrated how these efforts are less about the industrialised countries helping impoverished nations, but instead, the focus is more about the industrialised countries exploiting the natural resources of the often unfortunate “beneficiary” nations. He further contended that an investment in bicycles would do more to help the average Tanzanian, rather than a hundred miles of paved roadways. This in turn highlights, that walking and cycling is recognised and accepted as a way of life for the majority of people in the African Region, while also providing an economic conduit (WHO, 2004).

One of the challenges facing African cities is the increasing demand for efficient, reliable and low cost public transport. Currently the transport void is filled by small-scale public transport services which play an important role in public transport in the many African cities which are confronted with increasing populations, a decline in scheduled bus services, and the high operational costs of formal passenger transport services.



For example, South Africa's minibus taxi industry, Kenya's *matatus*, and Tanzania's *daladalas*, are an integral part of the passenger public transportation system, providing demand-responsive and affordable, but intensely competitive transport services, in all the cities, including Cape Town, Johannesburg, Dar es Salaam, Morogoro, Nairobi and Mombasa (Schalekamp, Mfinanga, Wilkinson, & Behrens 2009; Kinyanjui & Khayesi, 2005). It is estimated that *matatus* make 70% of the public transport trips in Nairobi, Kenya while the *daladalas* carry approximately 1.4 million passengers per day (i.e. making 43% of the trips). In Dar es Salaam, 45% of road trips were by non-motorised transport, and 6% by private cars (World Bank, 2002). The minibus taxis in South Africa provide approximately 63% of the national public commuter transport (NDOT, 2005; World Bank, 2002).

Another troubling reality is the fact that the majority of African countries do not have policies regarding investment in public transportation, and they tend to encourage walking and cycling as alternative modes of mobility to car travel. (Nilsson, 2004; Odera, Khayesi, & Heda 2003). It would therefore be prudent to formulate and enforce policies that take into account the possible adverse effects of an increase in vehicle density, cars with accelerated speeds, inebriated and inattentive adult drivers, and newly licensed drivers, in order to promote safe walking and cycling, an efficient public transportation system, as well as pragmatic land use for roads that accommodates all types of road users (WHO, 2004).

Public policies, such as those which promote the use of motor vehicles over walking and cycling, have exacerbated the problem, and in the process, transformed many small towns into ghost towns. This is because streets are predominantly designed for cars and not for pedestrians, and as a consequence, less people are walking and cycling, thus severing the social capital of such communities. Instead, more people are becoming confined to their homes

possibly because of the unpleasant and unsafe traffic environment, and the absence or lack of safe pedestrian walkways and recreational spaces. People are therefore opting for the safety of cars. Since streets and pavements are becoming more isolated, it's creating opportunities for violence and discouraging a sense of community. Surveys on walking have indicated that the children from families who do not own a car walk much more frequently as compared to those children whose family own a vehicle. It is not surprising that poor children are "outside" cars simply because they are not able to afford to be "inside" cars (Roberts, 2011)

Both Borowy (2013) and Roberts (2011) offer some critical and succinct reflections on reprioritising our dependence on motorisation by reclaiming the streets, and encourage walking and cycling; strengthening public transport; renegotiating or opposing new road construction, and paying the full social cost of using a car. They argue for land-use policies that reduce the need for car travel, and promote the building of "urban villages" clustered around public transport nodes, and not the sprawling car-dependent metropolises which appease the economic interests of all the stake-holders of motorised traffic, and who equate 'modernisation' with motorisation. The latter perception is deeply engrained in both HICs and LICs where the design of road infrastructure favours motorised vehicles, while there remains a scarcity or absence of the material infrastructure required for safer modes of travelling, especially in the LICs.

Class differences that separate car drivers and non-drivers in the LICs are especially prevalent, and non-drivers are accordingly the most vulnerable to a fatal injury. In addition, the child pedestrian who should benefit from policy changes, have no say in the political and policy-making decision processes that impact on their safety in their respective countries. Roberts (2011) exhorts us to all play our parts and to act now. According to Jacobs (1992), such collective concern would help to ensure the safety of our communities. The visibility of

children playing safely in a neighbourhood, is perhaps reflective of an indicator of urban safety, as is the presence of fish which indicates whether or not a river is polluted (Jacobs, 1992).

RTIs have been identified as an important element of the broader transport and development discourse. However, in recent years, the chief concern has been about the influence of motorisation and its impact on RTIs. This has stimulated critical questions and debate about the misdirection of development, thus highlighting the need for a fundamental rethinking (Borowy, 2013). The road traffic injury challenge is a complex phenomenon, and may be said to encompass the juxtaposition of both economic and social changes and events (WHO, 2004). It has been intimated that the impact of both an increase in urbanisation, and the burgeoning motorisation as a consequence of globalisation, warrants further research and critique.

RTIs are one of the leading causes of DALYs lost for children aged 0 to 14 years (WHO, 2008). Childhood pedestrian injuries and mortalities in South Africa remain a public health priority. Reflecting on the relevant literature, and the dearth of sound scientific African and, in particular, South African research in this domain. This study on fatal childhood pedestrian injuries endeavours to develop and contribute to the existing scientific child injury prevention evidence base. Accordingly, the study engages critically with the existing gaps in understanding the magnitude, circumstances, and determinants of child pedestrian mortality, as well as the injury response, so that appropriate and contextually relevant interventions are developed, advocated and implemented, for the prevention of childhood pedestrian injuries in South Africa.

In brief, this chapter contained an overview of the individual, familial and community risk factors, and contextual drivers associated with the epidemiology of childhood pedestrian

injuries within a global, African and national context. The issues highlighted in this chapter include the vulnerability of children to fatal pedestrian injuries as a result of the different phases in their physical, cognitive, perceptual and motor skills development, supervisory practices and beliefs, and the lack thereof, as well as children's daily exposure to hazards in the physical and social environment. The impact of poverty, rapid urbanisation and the increase in motorisation on child pedestrian injuries was also deliberated. The following chapter focuses on the theoretical perspectives of the distribution and aetiology of childhood pedestrian injury.

## **CHAPTER THREE**

### **THEORETICAL PERSPECTIVES ON THE DISTRIBUTION AND AETIOLOGY OF CHILD PEDESTRIAN INJURY**

Child traffic injury as a leading cause of mortality is a growing global public health problem that requires immediate attention, and has immeasurable consequences. Hundreds of thousands of children die each year from traffic accident injuries, while millions of others suffer the consequences of non-fatal injuries with devastating results for the individual, the family and society as a whole (WHO, 2008).

The determinants of child injury are multifaceted, and result from a complex interaction between individual factors, human factors, and the physical and socio-cultural environments (Peden et al., 2008; Sethi et al., 2008). In view of its complexity, child injury is often perceived as the so-called ‘appalling’ problem of public health (Hanson, Finch, Allegrante, & Sleet, 2012). Addressing the child injury problem is nevertheless considered possible (Albertsson, Björnstig, & Falkmer, 2003; Barnett, Balicer, Blodgett, Fews, Parker, & Links, 2003; WHO, 2008).

#### **1. DEFINITION OF CHILDHOOD**

Childhood is the time for children to be in school and at play, to grow strong and confident with the love and encouragement of their family, and an extended community of caring adults. It is a precious time in which children should live free from fear, safe from violence, and protected from abuse and exploitation. As such, childhood means much more than just the space between birth and the attainment of adulthood. It refers to the state and condition of a

child's life, to the quality of those years. Despite intellectual debates about the definition of childhood and cultural differences about what to expect of children, there has always been a substantial degree of shared understanding that childhood implies a separated and safe space (UNICEF, 2005). There is no universally acceptable age range as regards what constitutes childhood, and it is in fact, a socially composed concept that is both changeable and may be perceived via context, culture and capabilities (Hanson, Finch, Allegrante, & Sleet, 2012; Hendriks, Kremers, Gubbels, Raat, De Vries, & Jansen, 2013; Kickbusch & Gleicher, 2012; Mackay & Vincenten, 2010; Peden et al., 2008). The definition adopted by the Convention on the Rights of the Child focused on injuries that occurred in children under the age of 18 years (UNICEF, 1989).

Within the domains of health and the social sciences, there is a significant focus on the developmental differences that separate children from adults. Children's physical and cognitive abilities, degrees of dependence, activities and risk behaviours all change substantially as they grow older (Agran et al., 2001, Agran et al., 2003; Flavin, Dostaler, Simpson, Brison, & Pickett, 2006; Prüss-Ürsün & Corvalán, 2006, Rivara, 1995; Towner, Dowswell, Errington, Burkes, & Towner, 2005). However, as children develop, their curiosity and desire to experiment are not always matched by their capacity to appraise, understand or respond to danger (Bartlett, 2002). In addition, by virtue of their smaller size, children are less visible than adults, and this increases their risk in a road environment. Also when hit by a vehicle, they are more likely than an adult to sustain a head or neck injury (Toroyan & Peden, 2007). Moreover, small children also have difficulty in seeing over parked or moving vehicles, judging the speed of oncoming vehicles, and discerning the distance of a vehicle from the sound of its engine (Toroyan & Peden, 2007). Studies on children in traffic have shown that young children may lack the knowledge, skills and levels of concentration required to manage the road environment, no

matter how benign the road conditions. Their physical abilities may not match their cognitive abilities (Thomson, Tolmie, Foot, & McClaren, 1996).

Studies have also revealed differences among children younger than 15 years, for example boys, tend to suffer from more frequent and more severe injuries compared to girls (Bartlett, 2002; WHO, 2008). Various theories explain the differences in the injury rates between boys and girls as emanating from boys engaging in higher risk taking, and also indulging in more activities. In addition, as compared to girls, boys are often more impulsive, and they may also be 'socialised' differently, and therefore, allowed to explore with less restraint from their parents (Block, 1983; Eaton, 1989; Morrongiello & Rennie, 1998, Rosen & Peterson, 1990).

Despite this variety in their exposure to risk, the landmark Convention on the Rights of the Child (UNICEF, 1989), ratified by almost all governments, states that children throughout the world have a right to a safe environment and protection from injury and violence. Children are exposed to hazards and risks as they go about their daily lives, and they are vulnerable everywhere to the same types of injury. However, the physical, social, cultural, political and economic environments in which they live differ greatly. Their particular environments are thus extremely important, and, therefore, a theoretical framework that explains the importance of key risk types as well as their interaction is essential.

## **2. THEORETICAL FRAMEWORK FOR CHILDHOOD INJURY CAUSATION**

Barrs, Smith, Baker and Mohan (1998) cited that injuries are considered amenable to epidemiologic approaches, and as with many other diseases, they are deemed to be both preventable and controllable. Injuries and the events that lead to them are multifaceted and require inter-disciplinary scientific perspectives (Anderson, cited in Laflamme, Svanstrom, &

Schelp, 1999). A range of theoretical frameworks, models and typologies have been proposed as a result of injury research. This chapter discusses the traditional or classical theoretical contributions and specifically those within the ambit of public health approach.

## **2.1 Early Models of Injury Causation**

Within the context of public health, numerous definitions of the term `accident` have been proposed, for example: An accident is a process of parallel and consecutive events leading to a harmful consequence (Saari, 1986), or an accident is an event that results or could result in an injury (WHO, 1989). Thus, the connotation attached to the term `accident` is that it may be construed as unpreventable and unpredictable, and akin to `an act of God`, and reinforces the notion of an injury not been preventable.

The term `injury` was adopted as a `scientific` public health construct, and was defined as “the physical damage that results when a human body is suddenly subjected to energy in amounts that exceed the threshold of physiological tolerance – or else the result of a lack of one or more vital elements, such as oxygen” (WHO, 2008, pp. 1). The energy in question may be mechanical, thermal, chemical or radiated. Injury has broad connotations, with causality being either intentional (self-oriented or interpersonal violence) or unintentional, and the outcome determined by the act or event associated with the injury in question.

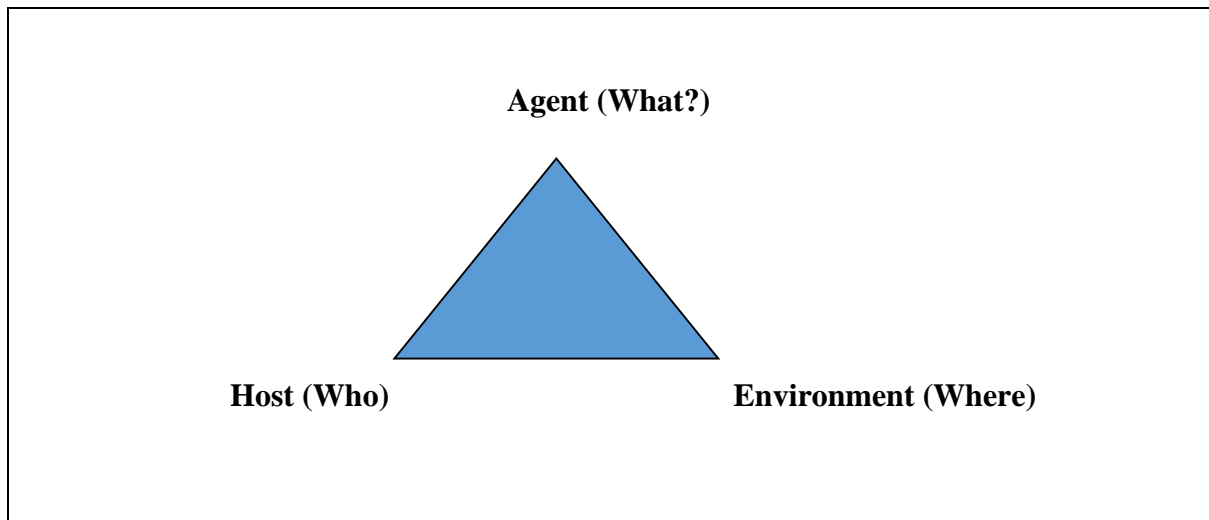
Time and “causation” or “level” are constructs that are included in the basic dimensional injury model, and in the theory developments in accident and injury research (Laflamme et al., 1999). Some of the frameworks postulated for accident-injury analysis, such as that of Heinrich in 1959 cited in Laflamme, (1999), and labelled the “Domino Model”, interpret the mechanism of causation as a linear flow of events characterised by the (1) environment which influences



(2) the human activities from which originate (3) the hazards, which produce (4) the crashes that translate into (5) injuries. For example, intervention in the accident-injury phase may involve the use of seat belts to counteract injuries which may arise as a consequence of an accident (Laflamme, et al., 1999).

Since the earlier conceptions of a scientific injury prevention paradigm, there has been a shift in the understanding of the concept of crashes to etiologic definitions of injury events as a health problem (Barrs, 1998; Welanders, Svanstrom, & Eckman, 2004). This, in turn, has led increasingly to injuries being analysed and contextualized within the same epidemiologic approach to other diseases, and with the focus on three causal categories, namely, host, agent and environment. These categories may be said to represent the three 'bricks in' Heinrich's Domino Model (Haddon, 1980; Laflamme et al., 1999).

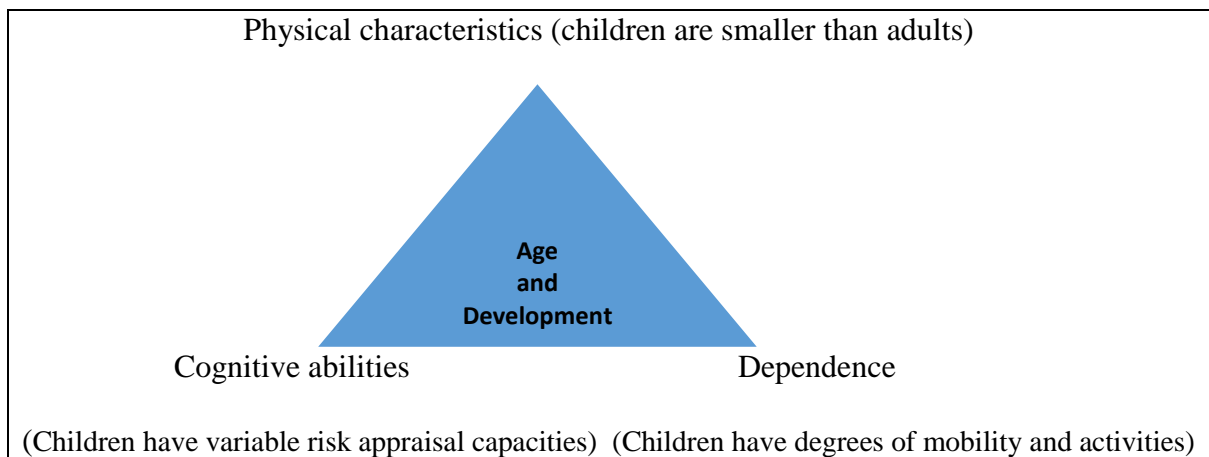
The epidemiologic parallel of infectious diseases and injuries is reflected in their common emphasis on the investigation of both the causative agents, and the circumstances in which they occur. This is illustrated by a traditional causal triangle with three corners or vertices, namely, an agent (What caused the injury?), host (Who was injured?) and environment (Where did the injury happen / What were the external factors that caused or allowed the injury to happen?) refer Figures 1 & 2). Energy and its transmission and also understanding the key contributions to an injury are important predictors that inform injury causation and, ultimately preventative interventions.



*Figure 1.* The epidemiologic triangle

*Source:* World Health Organisation (2008).

The figure below depicts an etiological model of a child injury:



*Figure 2.* Factors affecting child injury

*Source:* World Health Organisation (2008).

Further amplification of the previous linear models resulted in the development of systems-oriented models to understand the dynamic interplay within these risk categories (Laflamme et al., 1999), and also how to achieve homeostasis (balance) when a system is exposed to perturbations (disturbances), namely, a pedestrian being pushed or a driver and his/her car

skidding. Benner's (1975) described how and why stable systems, including potential dangers, are converted into unstable and dangerous modes, for example, accident or injury sequences (Laflamme, 1998). The emergence of risk or safety analysis drew on the evaluation of these injury models by focusing more on the inherent risks in systems and their improvement, instead of taking into account only a single individual's safety performance under given circumstances (Laflamme, 1998). More elaborate models and theories have since evolved, namely, macro and meso approaches. In addition, these models and theories are applicable elsewhere and not solely within the ambit of this child injury framework.

## **2.2 Haddon Matrix**

Charles Haddon was an epidemiologist. Based on his involvement in injury prevention, he developed a matrix to explain injury causation. Haddon posited that the design of the road transport system was often defective and required systemic modification. Haddon (1972) developed a matrix or template that identified possible risk factors that occurred before an accident, during the accident, and after the accident, and in relation to the individual, vehicle and environment. Haddon's theoretical and conceptual contributions to injury and safety research recommended an epidemiologic methodology to analyse injury events, and derived by cross-tabulating the trichotomy of host-agent-environment but with the inclusion of the dimension of time and into pre-event, event and post-event, and constituting a matrix of nine cells – the 'Haddon Matrix' (refer *Figure, 3*).

An important deviation from the epidemiologic approach was the deconstructing of the category of 'agent' with respect to injuries as merely something that produced the injury, i.e. stairs (fall) or motor vehicles (crash). Instead the 'agent' responsible for the injury was regarded as energy, (mechanical – wounds, thermal – burns and mechanical – poisoning). A further

adjustment to the model introduced a fourth category termed a ‘vector’ if biological or ‘vehicle’ if mechanical, and defined as a ‘carrier of the agent factor’, i.e. conveying the agent to the individual. This latter category ensured consistency in epidemiologic applications, including applications to injury (Laflamme, 1998).

Once the multiple elements associated with an accident have been identified and analysed, countermeasures may be developed and prioritised for implementation over the short-term as well as the long-term. As regards the pre-accident phase, it is necessary to select comprehensive countermeasures that could prevent the crash from occurring, while the accident phase is associated with countermeasures that prevent injury from occurring or lessening its severity if it does, indeed, occur. Finally, the post-accident phase involves all activities that reduced the unfavourable outcome of the accident after it has happened (refer to Figure 3).

	<b>Phase</b>	<b>Human</b>	<b>Vehicles and Equipment</b>	<b>Environment</b>
<b>Pre-crash</b>	Crash prevention	Information Attitudes Impairment Police enforcement	Roadworthiness Lighting Braking Handling Speed management	Road design and road layout Speed limits Pedestrian facilities
<b>Crash</b>	Injury prevention during the accident	Use of restraints Impairment	Occupant restraints Other safety devices Accident protective design	Accident-protective roadside objects
<b>Post-crash</b>	Life sustaining	First-aid skill Access to medical personnel	Ease of access Fire risk	Rescue facilities Congestion

*Figure 3. The Haddon Matrix*

*Source:* Haddon (1980).

### **2.3 Models of Child Injury**

Additional injury models have provided useful frameworks, and guided injury prevention by incorporating multiple determinants of injury (Hanson et al., 2005; Spinks, Turner, Nixon, & McClure, 2009), intervention planning (Runyan, 1998; Sleet, Hopkins, & Olson, 2003) and inter-sectoral collaboration (Cohen & Swift, 1999). However, these models did not engage with the specific nature of the child injury. Hence models were needed that encompassed and focus on the multifaceted dimensions of a child's vulnerability to injury, by taking into account the cognitive characteristics of the child in unfamiliar road environments, age and development, as well as dependence on protection and supervision (Allegrante, Marks, & Hanson, 2006; Towner & Mytton, 2009). General injury prevention initiatives which are designed for adults do not always protect children to the same extent (Bartlett, 1999; McDonell, 2007).

Scholtes, Schröder-Bäck, Mackay, Vincenten and Brand (2014) proposed a model based on aspects of the Haddon Matrix (Haddon, 1972), which had traditionally fitted the public health approach of primary, secondary and tertiary prevention, including assessing risk factors (Peden et al., 2008). The Haddon matrix was used as a tool for investigating severe bus and coach crashes (Albertsson, Björnstig, & Falkmer, 2003), identifying preventive strategies and assisting the decision making process (Runyan, 1998), and also for public health readiness and planning (Barnett et al., 2005; Brand, Schroder, Davies, Escamilla, Hall, & Hickey, 2006), including the Lens and Telescope model (Hosking, Ameratunga, Morton, & Blank, 2011) that was intended to provide a visual cue regarding the needs of the various age groups, and focusing the attention on enduring injury determinants such as socio-economic status and parental factors.

These authors contested that the traditional, nine-cell Haddon Matrix may be less suited to child injury prevention because the separation between environment, host and agent (e.g., a child's dependence upon adult supervision to secure his/her environment, and the child's lack of control over the environment) is difficult to capture in this version of the Haddon Matrix. As an alternative approach, the columns in the matrix are subdivided into host, and the agent into factors for the human, social and physical environment (refer *Figure 3*), thereby enabling more detail to be captured. Such detail may be particularly relevant for preventing child injury, and include detail on factors affecting parental supervision. This new approach may be used to examine a specific injury event (e.g. a specific car-pedestrian collision), or a group of injuries (e.g. child pedestrian injuries). Peek-Asa and Zwerling (2003) indicated that the causal pathway of most injuries is complex. They recommended a specific focus on the role of environmental modifications in intentional and unintentional injury control and prevention. Lund and Aaro (2004) conducted extensive reviews of previous studies in the literature, and proposed pathways for accident prevention with the emphasis on human, structural and cultural factors.

Volpe (2004) posited that, since Haddon (1972) had argued that preventative strategies should be founded on complex views of the person-environment interaction, there was a growing recognition that a synthesis of perspectives from multiple disciplines was required to understand the multilevel integration involved in injury prevention, i.e. the role of ecology or context in human behaviour and development. Volpe's contextual systems conceptual scheme model is an advancement on the Haddon model, and weaves together culture and society, communities and neighbourhoods, families and friends, life styles and ways of thinking into injury prevention/safety promotion.

The transactional nature of childhood injuries is a reminder to child caregivers that environmental and behavioural means of reducing risks are mutually linked but not exclusive, and that, together, they offer greater potential for improving safer outcomes than would otherwise be the case. Questions regarding *why* injuries occur have often taken precedence over questions relating to *how* injuries occur. However, both are important in injury prevention (Volpe, 2004).

### **3. TOWARDS A CHILDHOOD TRAFFIC INJURY SYSTEMS FRAMEWORK**

Road traffic collisions are a consequence of a dynamic combination of the elements linked to the constituents of the system comprising roads, road users, vehicles and the environment, and their mechanism of interaction. Certain elements contribute to the collision happening, and are therefore part of accident causation, while other elements magnify the effects of the collision and its impact on trauma severity. Some elements may be indirectly connected to road traffic injuries, the causes of which may be either immediate or accentuated by medium-term and long-term structural causes. Identifying the risk factors that contribute to road traffic crashes may help in the development of interventions that may decrease the risks associated with such factors (WHO, 2006).

Various analytical frameworks may be applied to detect risk factors that are germane to road traffic injuries and deaths, and provide contextual information that is correlated to the broader injury prevention framework. A theoretical framework is defined as a ‘conceptual model of how one theorises or makes logical sense of the relationships among several factors that have been identified as important to the problem’ (Sakaran, 2003, p. 19). The approaches that underpin the aetiology of fatal childhood pedestrian injuries are discussed below:

- Public Health Approach

- Systems Approach

### 3.1 Public Health Approach

The public health approach is a generic analytical framework that may be useful for identifying many health-related issues including injuries and violence (Krug, Sharma, & Lozano, 2000; Mercy, Rosenberg, Powell, Broome, & Roper, 1993). This approach may be helpful in guiding the entire injury process, from identifying the problem (surveillance), to analysing the causes (risk factors), and developing, implementing, and evaluating interventions (What works?). In view of the fact that the analysis of risk factors is one of the steps involved in this approach, it is relevant to include its application to road traffic injuries. The public health approach involves four interconnected pathways (refer Figure 4):

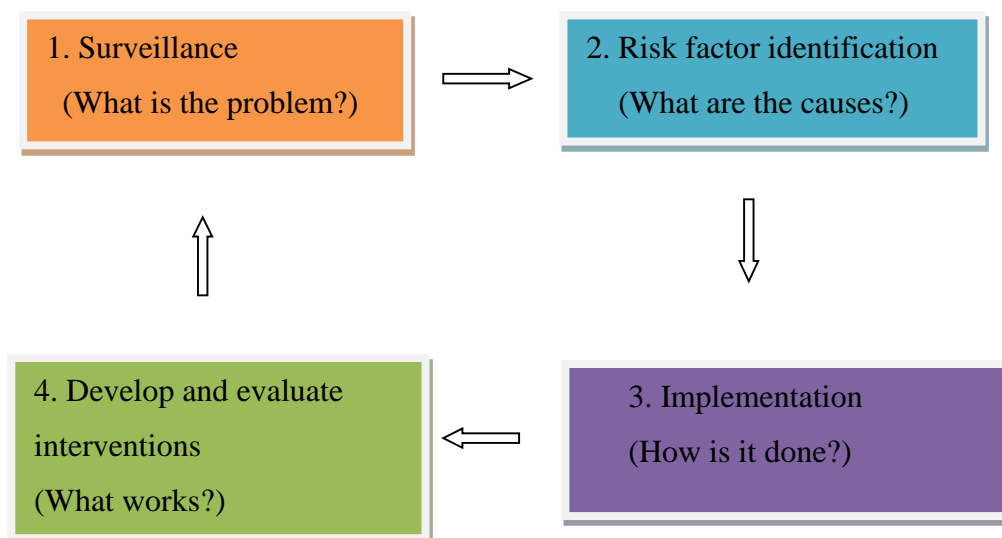


Figure 4. The public health approach

Source: WHO (2006).

The conventional analysis of risk examined the road user, vehicle and road environment separately. Researchers may have inclined to look for one or a few elements, instead of conducting the analysis on multiple elements.



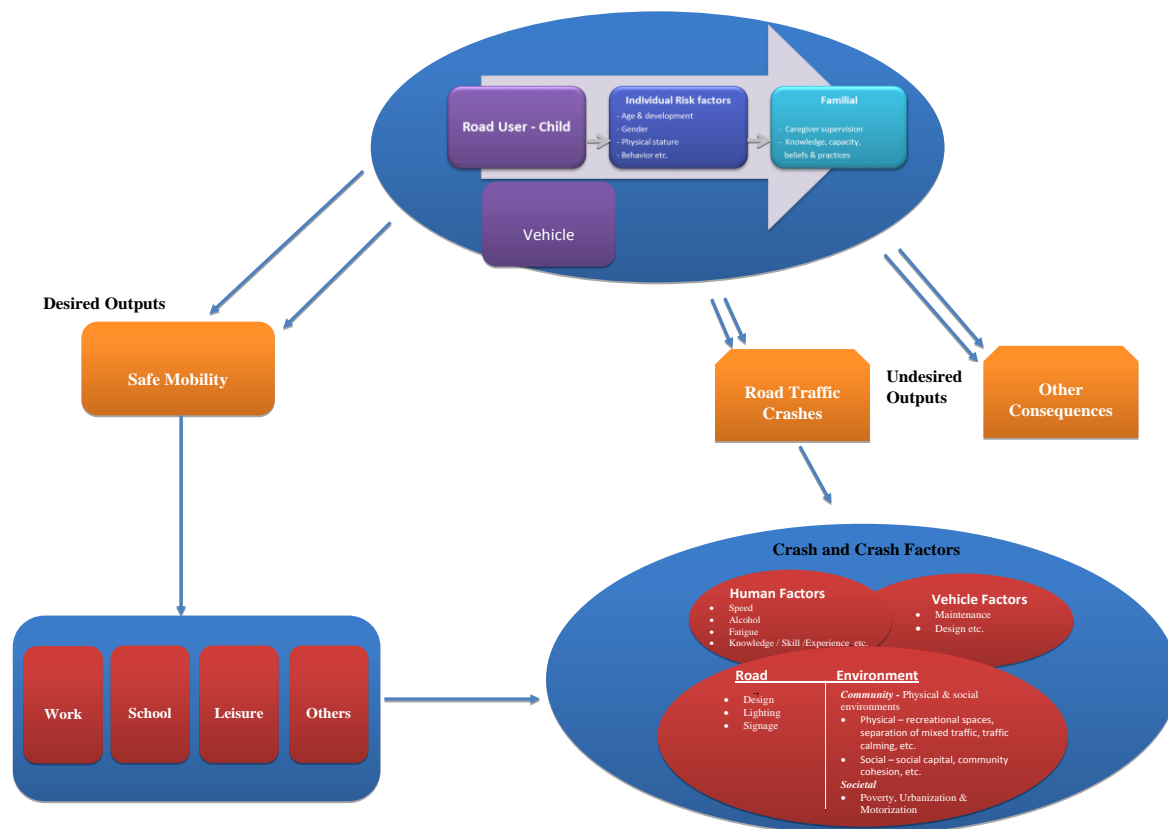
### **3.2 Systems Approach**

The systems approach (in terms of which the interactions between various components are taken into account) was built on Haddon's insights, and was aimed at untangling and correcting the elements that may have contributed to the key sources of the errors, or design flaws that may have resulted in fatal injuries, crashes or severe trauma, as well as contributed to fatal crashes or crashes that resulted in severe injury, or helped to moderate the intensity and consequences of injury. The essence of the systems approach involves taking account the interplay of multifaceted elements, including the role of different agencies and actors in prevention efforts.

Road traffic injuries are a multidimensional problem that requires a comprehensive lens when the determinants, consequences and outcomes are examined. Road traffic systems are highly complex, and may be hazardous to human health. Elements of the system include motor vehicles, roads, and road users together with their physical, social and economic environments. Thus, making a road traffic system less hazardous requires a systems approach. This is made possible by understanding the system holistically, including the interplay between the elements of the system, and identifying the potential for intervention. This approach takes into account both the shortcomings of human beings, and also the vulnerability of the human body to trauma. According to Peden (2004), a safe road traffic system is one that accommodates and compensates for human vulnerability and fallibility.

The adapted road transport system is depicted in Figure 5. The road transport system illustrates the interplay and interlinking of various elements of the system that either produced a desired and or undesired outcome of injury. The main principle is that a road traffic crash or collision is the outcome of the interaction among a number of factors and subsystems. It is therefore

essential to consider all aspects of causation in the system and its subsystems when planning interventions aimed at decreasing the likelihood of collisions and mortalities. Some of the elements identified in research, and that influence the exposure to the risk of RTIs include, the level of economic development and social deprivation; demographics (age and sex); land-use planning practices which influence the lengths of road trips and modes of travel; a combination of high-speed motorised traffic and vulnerable road users, and insufficient attention to the integration of road functions as regards decisions about speed limits, road layout and design. In view of the fact that the elements of an accident include human and social factors, as well as the physical and technical components of the road and transport system, the shift from adopting an approach of simplistic injury causation to a multidisciplinary approach, afforded the opportunity to design appropriate measures that may prevent injury, and promote safety in road transport systems.



*Figure 5. A systems approach to child risk factors*  
*Source: Adapted from Muhlrads and Lassarre (2005).*

Muhlrads and Lassarre (2005) posited that a systems approach attempts to identify and rectify the major sources of the error or design weaknesses that contribute either to fatal crashes or to crashes that result in severe injury, as well as to mitigate the severity and consequences of injury. The elements of the system include motor vehicles, roads, and road users together with their physical, social and economic environments. Muhlrads and Lassarre (2005) also highlighted that the essence of using the systems approach is to consider not only the underlying factors in respect of road traffic crashes, but also the role of various agencies and actors in the causes and impacts of such crashes, as well as in intervention measures aimed at preventing these crashes.

This study adapted the existing road and transport system framework developed by Muhlrads and Lassare (2005), and reconfigured it into a systems approach to the child risk factors in relation to child pedestrian injuries (see Figure 5). A systems approach to child risk factors encompasses an eco-systemic multidimensional perspective on the interplay of the identifiable individual and familial risk factors associated with the road user (child pedestrian), as well as various contextual drivers and crash factors (human, vehicle, road and environment), that both contribute to and mitigate the consequences of motor vehicle crashes, and that either result in desired outputs (safe mobility), and or undesired outputs (fatal crashes and / or pedestrian deaths), and also other outcomes.

The individual risk factors associated with the road user (pedestrian) include age, level of development, sex, physical stature, behaviour etc. and also familial factors (caregiver supervision, knowledge, capacity, beliefs and practices), while the crash factors are associated with human factors (speed, alcohol, fatigue, knowledge, skill and experience, etc.), vehicle factors (maintenance, design etc.), road features (design, lighting, signage etc.), environmental factors (physical – recreational spaces, separation of mixed traffic, traffic calming, etc.), social factors (single parent, low maternal education, social capital, community cohesion, etc.) and societal factors (poverty, urbanisation, and motorisation). Both the risk and moderating influences of all these factors on child pedestrian injuries and deaths are explicated in this study.

In short, the chapter discussed the nature of an injury, its causation and countermeasures for the prevention of injury. This was made possible by the design of an initial matrix of injury causation known as the Haddon Matrix. The Haddon Matrix later evolved into a more

comprehensive and complex framework /model that integrated and untangled the various factors which are associated with the pre-injury, injury and post-injury events, as well as proposing countermeasures to prevent future injuries by applying a systems framework. The research methodologies that are discussed in the next chapter encapsulate the relevant literary and conceptual paradigms, and transform them into demonstrable analytical applications. The data collected was analysed in an attempt to disentangle the complex interplay of the various circumstances that contribute to a fatal child pedestrian injury.

## **CHAPTER FOUR**

### **RESEARCH DESIGN**

This chapter contains an overview of the research focus and objectives, as well as the study design, study population, and the data sources that were utilized. The overarching focus of the study was to describe the distribution, patterns, circumstances and neighbourhood characteristics of childhood pedestrian mortality from birth to 14 years in Johannesburg. The study was guided by the following four study objectives:

- Firstly, to describe the incidence, demographics and circumstances of childhood pedestrian mortality in Johannesburg (2001–2010).
- Secondly, to identify the demographic and circumstantial risks that differentiate childhood pedestrian mortality from childhood motor vehicle passenger mortality in Johannesburg (2001–2010).
- Thirdly, to identify the demographic and circumstantial risks that differentiate childhood pedestrian mortality from childhood burns and drowning mortality in Johannesburg (2001–2010).
- Fourthly, to identify neighbourhood-level predictors of childhood pedestrian mortality in Johannesburg (2001–2010).

#### **1. STUDY POPULATION**

Childhood unintentional injuries, and in particular, fatal pedestrian injury rates in urban South Africa are significant public health challenges. Children are identified as a vulnerable group in

respect of pedestrian injuries and mortality (Donson, 2008; Prinsloo, 2007). The thesis focused primarily on pedestrian mortality because it is ranked as the highest unintentional injury among children from birth to 14 years old (Donson, 2008; Donson & Van Niekerk, 2012; Matzopoulos, 2004; Prinsloo, 2007). Johannesburg was selected mainly because childhood pedestrian mortality ranks persistently among the top causes of unintentional injury mortality each year in the city among children from birth to 14 years old (Donson, 2008; Prinsloo, 2007). In addition, the total number of mortalities that occurred during this time period was deemed sufficient to conduct a statistical analysis. The other important causes of unintentional injury mortality such as falls and poisonings, etc. were precluded because their low numbers were insufficient for the purposes of statistical analysis. The childhood demographics for Johannesburg are comparable to those of the other cities in South Africa. Johannesburg is regarded as the cosmopolitan and industrial hub of the country, and is also the largest city in the Gauteng province. Furthermore, Johannesburg is also undergoing rapid inner city transformation which is compounded by increasing urbanisation and motorisation (RTMC, 2011).

For the purposes of this study, pedestrian mortality for children in the 0 to 14-year age category was adopted using the WHO guidelines for classifying children into age groups 0 to 4 years old, 5 to 9 years old and 10 to 14 years old (WHO & UNICEF, 2008).

## **2. DATA SOURCES**

The thesis drew on two principal data sources, namely, the NIMSS and Census 2001.

## **2.1 The National Injury Mortality Surveillance System**

Information on childhood pedestrian mortality, including child victims as motor vehicle passengers, and non-traffic or unintentional injury deaths, such as burns and drowning, was extracted from the NIMSS. Demographic data on the child (i.e. sex, age, and population group<sup>1</sup>), as well as temporal (i.e. year, month, day, and hour), and spatial (i.e. scene of mortality) information, were used for the statistical analysis. Information on socio-demographic and neighbourhood characteristics that were contextually relevant was obtained from the Census 2001, and included in the statistical analysis. In view of the fact that the NIMSS was the principal source of the data pertaining to the four research objectives, a detailed description of the NIMSS follows. The statistical techniques relevant to each research objective that were applied in the study are discussed at a later stage.

The NIMSS was developed in order to provide epidemiological data on injury mortality in South Africa in collaboration with the state medico-legal and forensic chemistry services pertaining to all injury deaths (Donson, 2008). According to the Inquest Act (No. 58 of 1959), all non-natural deaths in South Africa must be reported to the police, and are subject to a medico-legal investigation. Non-natural deaths are caused by an active intervention and are usually understood as an accident (implying no unreasonable voluntary risk), misadventure (accident following a wilful and dangerous risk), suicide or homicide. Each non-natural death that enters the forensic medico-legal system requires the investigating forensic pathologists and

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<sup>1</sup> In South Africa, the terms ‘white’, ‘black’, ‘coloured’ (referring to mixed heritage) and ‘Asian’ refer to the apartheid classifications of various population groups (see also the ‘Results’ section). The researcher does not subscribe to these contentious terms of racial classification and social construction of peoples that are devoid of any anthropological and scientific basis. In this study, the terms are used to reflect the differential manner in which the earlier policies of racial segregation, or apartheid, has impacted on the life experiences of the various population groups.



forensic officer to complete a single data form for the NIMSS that records 21 items of information. These include the demographics of the victim (age, sex and race), time of death, scene and place (province, town, and suburb) of injury mortality, external cause and apparent manner of death (homicide, suicide, accidental, undetermined) and blood alcohol concentration (BAC) levels (Donson, 2008).

The NIMSS's classification of the external cause of death is based on the WHO International Classification of Diseases (ICD 10), which is a coding system developed by the World Health Organisation (WHO), that translates the written description of medical and health information into standard codes. The *external cause* of death refers to the mechanism or circumstance that preceded the death (Donson, 2008). For a pedestrian death, the following category applies, namely, motor vehicle driver. The *apparent manner* of death describes the intention prior to the injury that resulted in the death, and is divided into the following five categories, namely, violence (intentional interpersonal injury), suicide (intentional self-directed injury), transport-related, other unintentional injuries (e.g. drowning), and undetermined (Burrows, 2005). Since establishing the final manner of death involves a lengthy process which is determined only after the police investigations and the court proceedings which may take between two to five years to complete, the NIMSS records only the *apparent manner* of death determined by the medical practitioner, and this is for research purposes only (Burrows, 2005). The NIMSS collects fatal injury data directly from the Forensic Pathology Services (FPS), and the information is based on the post mortem results. Contextual information is not always accessible soon after an injury event, and may be obtained only through police investigations (Dahlberg & Krug, 2002; United Nations Office on Drugs and Crime-UNODC, 2011).

Once all the data has been captured on the NIMSS form, the staff at the medico-legal services and laboratories then enter the data into a computerised database. Data that has not been comprehensively captured, is returned to the laboratories for verification before it is accepted by the Violence, Injury and Peace Research Unit (VIPRU). At the end of each year, the data from all the participating medico-legal services and laboratories is sent to the Violence, Injury and Peace Research Unit (VIPRU), formally known as the Safety and Peace Promotion Research Unit (SAPPRU), which is co-directed by the Medical Research Council (MRC) and the University of South Africa (UNISA). Data on the blood alcohol concentration (BAC) levels of victims from the Forensic Pathology Services and Forensic Chemistry Laboratories is also sent to VIPRU, and integrated into the database. After receiving data from the FPSs, the NIMSS project team cleans up and checks the data. Any queries are followed up with the forensic staff concerned and subsequently corrected, if necessary. The datasets from each FPS facility are then collated into one dataset per province. The new electronic version of NIMSS has added vehicle type as a category. The NIMSS is a collaboration between the South African Department of Health (DoH) and VIPRU, and adheres to strict ethical standards as prescribed by the DoH, MRC and UNISA (Suffla, van Niekerk, & Arendse, 2008).

The NIMSS system started collecting fatal injury data in 1999 at ten medico-legal laboratories across the country. From 2001 to 2005, the system maintained full coverage of all injury deaths in four major metropolitan centres in South Africa, namely, Cape Town, Durban, Johannesburg and Pretoria. In 2006, with the transfer of Forensic Pathology Services (FPS) from the South African Police Service (SAPS) to the Provincial Departments of Health, several of the medico-legal services/laboratories lessened their collaboration with NIMSS. Since 2008 and until today, NIMSS has secured full coverage of all injury deaths in the province of Mpumalanga

(includes urban and rural data), and southern Gauteng, which incorporates two major South African cities, Johannesburg and Ekurhuleni.

## **2.2 South African National Census**

The South African National Census is the most exclusive and comprehensive socio-economic and geographic database which is conducted every ten years by Statistics South Africa (StatsSA). The Census is the prime means through which population and housing statistics on every individual person within defined geographical areas in a country are collected, processed and published (StatsSA, 2012b). The South African Census is conducted every ten years by StatsSA. The Census incorporates population and housing data such as sex, age, education level, ethnic composition, employment, recent migration, household structure and constituents, and dwelling types and services (StatsSA, 2001a). Census data is used by various government ministries for planning and budgeting purposes. It is also of benefit to the general public, researchers, journalists, NGOs, civil society, lobby groups and others who use the data for their work. On another level, the Census provides a narrative about the people behind the census forms. For example, it portrays the hopes of the migrant workers who leave one province for another, or the successes of a particular age cohort in the labour market. The stated purpose of a census is to provide information that may be used in a normative sense i.e. what should be done to improve the economic and social circumstances of the population (Berkowitz, 2012). The Census is considered to be a premier statistical publication by government, and has the potential to impact profoundly on policy. There is however, some concern about the accuracy and validity of some of the data in view of discrepancies in terms of coverage, counts, boundary demarcations and geo-coding (Berkowitz, 2012). Nevertheless, despite these constraints, for the purposes of this thesis, the Census represents the most widespread source on the population at both the city and the neighbourhood level.

### **3. SETTING**

Johannesburg is the financial and commercial hub of South Africa, and also of the African continent. The City of Johannesburg was chosen for this study as it is the most densely populated and urbanised municipality in South Africa, and home to 4.435 million people. The annual population growth rate is 3.2%. The population in Johannesburg accounts for approximately 36% of the population of Gauteng, and 8% of the national population. Over the last decade the city has been growing rapidly. The unemployment rate is 25.0% (StatsSA, 2011). Johannesburg was selected for the purposes of this study mainly because the pedestrian mortality in children from birth to 14 years in the city consistently ranked among the top causes of unintentional deaths (Donson, 2008; Prinsloo, 2007). The city is also home to both the wealthy and the poor, as well as refugees, global corporations and emerging enterprises. The demographics of Johannesburg indicate a large and ethnically diverse metropolitan area. As the largest city in South Africa, its population is defined by a long history of local and international migration. Johannesburg's average household income in 2005 translated into an average personal disposable income of R51 000 per head of population (City of Johannesburg Economic Development Policy and Strategy Framework, 2008). Both the apartheid legacy and the adoption of neoliberal policies have influenced social development in the city: the Black African population continues to exhibit a low level of performance at the matriculation and tertiary educational levels; 16% of households lack municipal sanitation, 15% do not receive municipal electricity, 3.6% do not have a water supply, approximately 116 827 families live in informal settlements, about 108 000 families live in illegal backyard dwellings, and there are some 4 500 homeless or "street people" (City of Johannesburg Economic Development Policy and Strategy Framework, 2008). Despite the fact that from 2000 to 2010, the City of Johannesburg invested in infrastructure and housing development, while deprivation, poverty and unemployment remain geographically concentrated, and the land distribution and spatial

settlement patterns continuing to bear the marks of apartheid (Makhanye, 2013). The city is also experiencing a high influx of people, and this in turn increases the densification of informal settlements. The population pyramid indicates that the city's population is predominantly young. This may be attributed to young people migrating from other parts of the country to Johannesburg to seek employment.

While the majority of the city's residents do not own vehicles, the middle-income residents are car-oriented. Inequality is evident in the City of Johannesburg: the Gini coefficient for the city was 0.63 in 2009. The main economic sectors include the finance and business services, community services and manufacturing. The suburbs of Johannesburg include Alexandra, Diepkloof, Diepsloot, Ennerdale, Johannesburg South, Lawley, Lenasia, Lenasia South, Meadowlands East, Meadowlands West, Midrand, Orange Farm, Pimville, Randburg, Roodepoort, Sandton and Soweto.

In January 2015, there were 1 603 106 motor vehicles in the City of Johannesburg with an annual increase in traffic of 7%. The number of vehicles in Gauteng is 4 168 142, with an average increase of 0.18% (Chakwizira, 2007; RTMC, 2013). South Africa's total road network comprises approximately 747 000 km, the longest network of roads of any African country. The South African National Road Agency (SANRAL) is responsible for the country's network of national roads, which cover about 16 200 km. According to the SA Institute of Civil Engineering, there are about 185 000 km of provincial roads, while the municipal road network totals around 66 000 km (South Africa Info, 2012).



Figure 6. Map of South Africa

Source: Google maps



Figure 7. Map of Johannesburg

Source: StatsSA (2001).

**Table 1. Population for children aged 0 to 14 years in the City of Johannesburg (2001-2010)**

Age in years	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	All years
0-4	265635	282343	299052	315761	332470	349179	365887	382596	399305	416014.2	3408246
5-9	235012	243357	251703	260048	268394	276739	285085	293430	301776	310121.5	2725668
10-14	232946	237413	241881	246349	250817	255285	259752	264220	268688	273156.2	2530511
0-14	733593	763115	792637	822159	851681	881204	910726	940248	969770	999292	8664425

Source: Adjusted from Census (2001).

Table 1 represents the populations for the different age categories across a ten-year period, namely, 2001 to 2010, for the City of Johannesburg. The age category 0 to 4 years has the highest population, with a gradual increase each year, followed by the 5 to 9 years, and 10 to 14 years age categories respectively.

**Table 2. Population groups for the City of Johannesburg (2001–2010)**

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
<b>Indian</b>	29700	31558.88	33417	35276	37135	38994	40853	42712	44571	46429	380649
<b>Black</b>	554877	581600.6	608324	635047	661771	688495	715218	741942	768666	795389	6751333
<b>Coloured</b>	57593	58508.43	59423	60339	61254	62170	63085	64000	64916	65831	617124
<b>White</b>	91424	91448.07	91472	91496	91520	91544	91568	91592	91616	91640	915323

*Source:* Adapted from StatsSA (2001).

Table 2 represents the populations for the different population groups in the City of Johannesburg. Children belonging to the black population group had the highest representation, followed by whites, coloureds and Indians for the ten-year period. There was also a gradual increase in all population groups from 2001 to 2010.

**Table 3. Sex population for children in the City of Johannesburg (2001–2010)**

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
<b>Male</b>	364647	380022	395398	410774	426150	441526	456902	472278	487654	503030	4338386
<b>Female</b>	368946	383092	397238	411384	425530	439677	453823	467969	482115	496261	4326039

*Source:* Adjusted from Census (2001).

Table 3 represents the sex population for the City of Johannesburg over a ten-year period, 2001 to 2010. There are slight variations in the male to female ratios across the years, although in total for the ten years, there were more males than females.

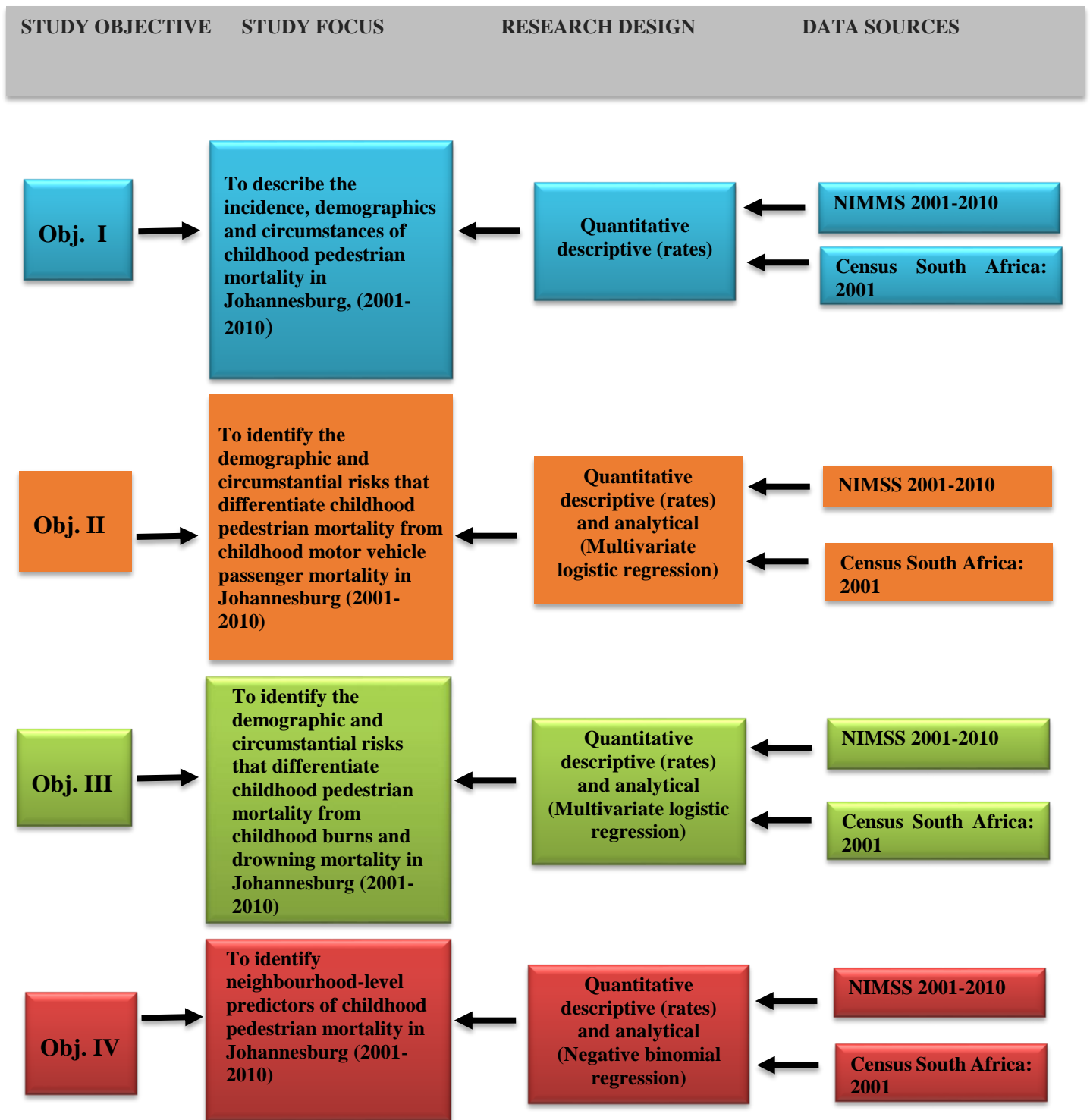


Figure 8. Objectives, research design and data sources for childhood pedestrian mortality

The following section discusses the methodology used to achieve each of the research objectives.



#### **4. STUDY DESIGN, DATA SOURCES AND ANALYSIS**

The first objective of the thesis was to describe the incidence, demographics and circumstances of childhood pedestrian mortality (2001–2010) for children from birth to 14 years in Johannesburg. The method of analysis involved the quantitative description of mortality rates expressed as per 100 000 population. The data sources used included the NIMSS and Census 2001. The second research objective was to identify the demographic and circumstantial risks that differentiate childhood pedestrian mortality from childhood motor vehicle passenger mortality in Johannesburg (2001–2010). For this objective a multivariate logistic regression analysis was conducted on childhood pedestrian mortality in relation to motor vehicle passenger deaths. The sources of data used were the NIMSS and Census 2001. The third research objective was to identify the demographic and circumstantial risks that differentiate childhood pedestrian mortality from childhood burns and drowning mortality in Johannesburg (2001–2010). The method of analysis used was a multivariate logistic regression analysis of childhood pedestrian mortality in relation to burns and drowning deaths. The sources of data used were the NIMSS and Census 2001. The fourth research objective was to identify neighbourhood-level predictors of childhood pedestrian mortality in Johannesburg (2001–2010). The method of analysis used was negative binomial regression, and the data source was the NIMSS and Census 2001. The period of analysis for the four objectives was 2001 to 2010 (refer Figure 8).

#### **4.1 Overall Incidence of Selected Child Injury Mortality**

##### *4.1.1 Data source*

Mortality data for children fatally injured as pedestrians, motor vehicle passengers, and non-injury traffic deaths (burns and drowning) for Johannesburg from 2001 to 2010 was extracted from the NIMSS. The data included the victim's sex, population group, external cause of death

(e.g., pedestrians, motor vehicle passengers, burns and drowning), day on which death occurred (Sunday, Monday, Tuesday, Wednesday, Thursday, Friday and Saturday), time of death (0h00–03h59, 04h00–07h59, 08h00–11h59, 12h00–15h59, 16h00–19h59 and 20h00–23h59); and month of death (January to December). Blood alcohol analysis (BAC) was not deemed appropriate for the purposes of this study, since the study population was children from birth to 14 years old, and because there were minimal cases, they were excluded as a source of data for statistical analysis.

#### *4.1.2 Data analysis*

The results for objective one are presented as follows: 1) overall incidence over time; 2) incidence by age, sex and population group; and 3) occurrence by time of day, day of the week, and month. Age-specific rates for pedestrians, children as motor vehicle passengers, burns and drowning were calculated using age categories 0 to 4 years old, 5 to 9 years old, 10 to 14 years old and 0 to 14 years of old, and aggregated for the ten-year period in order to describe the distribution of childhood mortality across these age groups. For each of these rates calculation, the numerator was either the number of pedestrian, motor vehicle passenger, burns and drowning deaths in each of the specified age categories, while the denominator was the total population in Johannesburg for each of the indicated age groups, and multiplied by 100 000. Frequencies were also computed for the circumstances of child pedestrian mortality by time of day, day of the week and month. This is similar to the method used to calculate childhood pedestrian and other unintentional injury deaths rates in other studies conducted in South African (Matzopoulos, 2004; Prinsloo, Matzopoulos, & Sukhai, 2003).

For the purposes of this thesis, base population estimates were derived by the linear interpolation of the 2001 and 2011 census data for the age group, population group, and sex

specific population distributions in Johannesburg (Statistics South Africa, 2003; Statistics South Africa, 2012a). The 2001 Census was interpolated by using the 2010 Census to ascertain the closest approximation for the population totals (i.e. the denominator data) for the calculation of childhood pedestrian, motor vehicle passenger and non-traffic (burns and drowning) mortality rates for the 0 to 4 year olds, 5 to 9 year olds, 10 to 14 year olds and including the 0 to 14 year age group. The 2001 Census, which was the most recent at the time this thesis was conducted, provided the data on the socio-structural characteristics of neighbourhoods in Johannesburg, as the Census 2010 was not officially available in the public domain at the time of the study. The 2001 South African National Census population estimates for the City of Johannesburg were used for 2001 rates computations (StatsSA, 2003). The 2001 Census interpolated population estimates for the City of Johannesburg were used (StatsSA, 2003) by adjusting for the years 2001 through to 2010, using the 2011 Census population growth rates (StatsSA, 2012).

Interpolation is a method of constructing new data points within the range of a discrete set of known data points. It is the simplest method available to obtain values at positions in between data points. The points are joined by a straight line segment (Bourke, 1999). Linear interpolation is a widely accepted, easily understood application and a valid method which may be used to estimate intercensal population counts when working with human population figures, and the interval between the data points is 10 years (Bourke, 1999; Coulson & Joyce, 2003). In order to approximate the population of the City of Johannesburg for the years 2001 to 2010, the average annual percentage change between the 2001 and 2011 censal data points was calculated, and then applied to the baseline value to estimate age, population group and sex specific population denominators for the intervening years, namely, 2001 to 2010.

Adjustments had to be made to make provision for the addition of the “Other” category in the 2011 Census, which had been included to accommodate those South Africans who declined to classify themselves in terms of race. Based on the assumption that individuals in the four ‘racial’ categories were equally likely to choose “Other”, the number of people in the Indian, black, coloured and white population groupings in the 2011 Census population estimates were adjusted upwards. Specifically, the population in the “Other” category was distributed across the four ‘race’ classifications which had been used in the 2001 Census data, and hence also in this study, and based on the relative size of the four groups for each age-sex category. The adjusted estimates were used as the 2011 data point for the linear interpolation undertaken. In the context of this thesis, this is understood as follows. A total of 280 454 people listed themselves as "Other" in the 2011 Census. These were South Africans who refused to classify themselves in terms of the racial nomenclature introduced by the apartheid system. In view of the fact that the option of “Other” was not available in the 2001 Census, it may be assumed that, if it had been available, an estimated number of people would have selected this option. In order to adjust for this anomaly in the 2001 Census data, interpolation was necessary for the purposes of this study as the period in question was between 2001 and 2010. Specifically, it was thus assumed, that the same percentage of each age-sex group would have selected “Other” in 2001, as was the case in 2011, and also that participants across the four population groups in the 2001 Census were equally likely to have chosen “Other.” In order to maintain the same total number of people in each age and sex group, the number of people in each of the four population groups in 2001, and who had been included in the 2001 Census was adjusted downward. Using this procedure, it was assumed that the “Other” population group would exhibit the same annual growth rate as the general population in each specific age and sex category. Childhood pedestrian and motor vehicle passenger, as well as non-traffic (burns and drowning) mortality rates by sex and population group, were computed following the

procedures outlined above in order to examine the distribution of childhood deaths across the demographic groups.

The descriptive statistics on the mortality rates and the scene of death were too small, and therefore not used in the analysis. Frequencies and percentages for the temporal data (month, day, and time) were computed separately for males and females, and for the population groups (Indian, coloured, black African and white). The total number of child pedestrian mortality for 0-14 years old was 756, however, for sex specific mortality rates, information on 9 pedestrian cases were not available and therefore discarded ( $N = 747$ ), and similarly 5 pedestrian cases were not available for population specific rates for children, ( $N = 751$ ). All the analyses were conducted using IBM Statistical Package for the Social Sciences (SPSS), Statistics for Windows, Version 22.0.

## **4.2 Demographic and Circumstantial Risks: Childhood Pedestrian Mortality versus Motor Vehicle Passenger Mortality**

### *4.2.1 Data source*

Pedestrian and motor vehicle passenger mortality data for Johannesburg over the ten-year period in question was extracted from the NIMSS. This data included age groups, sex, population groups, and temporal information. In order to discover any missing data, a missing values assessment was conducted on the dataset to identify a pattern of missing data. Mortality data for children, including all those injured as pedestrians and motor vehicle passengers, in Johannesburg from 2001 to 2010 was extracted from the NIMSS. The data included the victim's sex, population group, external cause of death (e.g., motor vehicle passengers, day of death (Sunday, Monday, Tuesday, Wednesday, Thursday, Friday and Saturday), time of death (0h00–03h59, 04h00–07h59, 08h00–11h59, 12h00–15h59, 16h00–19h59 and 20h00–23h59);

and month of death (January to December). Of the 756 pedestrian cases that had been recorded for the 0 to 14-year-old age group by the NIMSS, 85 cases were found to have a high count of missing values across all variables, and they were therefore excluded from the analysis. This resulted in a total of 671 fatal child pedestrian injuries being used for the analysis. Subsequently, this doctoral thesis may have underestimated some of the rates and proportions on which it reported. However, for the City of Johannesburg, the NIMSS represents the only injury surveillance system that provides 29 baseline data categories for descriptions of fatal injury epidemiology, and also monitors the efficacy of safety prevention initiatives.

#### 4.2.2 Data analysis

The results for objective two are presented as follows: 1) predictors of child pedestrian and motor vehicle passenger mortality, and 2) logistic regression analysis models that examined the *socio-demographic variables* associated with pedestrian versus motor vehicle passenger mortality (Logistic regression analysis-Model 1) and a model that assessed *temporal factors* (Logistic Regression Analysis-Model 2). Logistic regression may be used as a powerful analytical approach for predicting a dichotomous outcome and or logistic regression was used to determine the association, if any between a range of explanatory variables, and child pedestrian and as motor vehicle passenger mortality. In its simplest form, logistic regression makes it possible to predict to which of two categories a person is likely to belong, given certain other information (Field, 2009). Alderden and Lavery (2007) define logistic regression is an appropriate statistical procedure for a dichotomous, binary coded, dependent variable that represents the logarithm of the odds of having been exposed to a pedestrian fatality. In addition, it is a procedure that offers more flexibility than ordinary least squares regression or linear discriminant function analysis.

In order to ascertain the predictors of child pedestrian and motor vehicle passenger mortality, the circumstances of the occurrence of such mortality were examined by means of multivariate techniques based on the coded values of several variables descriptive of the type of mortality, i.e. pedestrian and motor vehicle passenger, age group (0–4, 5–9, 10–14 years); sex (male and female), population group (Indian, black, coloured and white), time of death (06h00–11h59, 13h00–18h59, 20h00–22h59 and 12h00–4h59), weekday on which death occurred (Monday, Tuesday, Wednesday, Thursday and Friday) or weekend (Saturday & Sunday), holiday time (December, January, April, July and September) and non-holiday time (February, March, May, June, August and October).

In order to uncover the socio-demographic variables associated with pedestrian versus motor vehicle passenger mortality (Logistic Regression Analysis-Model 1), and temporal factors (Logistic Regression Analysis-Model 2), an initial analysis was conducted to ensure that the underlying assumptions of logistic regression had not been violated. Initially, the association between type of mortality, and these factors mentioned above, the variables above were tested by means of a chi-square test and pseudo  $R^2$  (Nagelkerke value) to ascertain whether the overall logistic regression model was indicative of been robust. The logistic regression focused on two discrete outcome categories, namely, child pedestrian mortality, and motor vehicle passenger mortality with the latter being coded as the reference category. Two logistic regression models were computed. The first model examined socio-demographic variables only, while the second model added temporal variables to the analysis. The model coefficients were exponentiated so that they could be interpreted as adjusted odds ratios (ORs), with 95% confidence intervals (CIs) being used to assess the magnitude and significance of the adjusted multivariate associations. A p-value of below 0.05 was considered significant. The statistical analyses were performed using the IBM Statistical Package for the Social Sciences (SPSS Version 22). The

words independent variables (IVs), variables, factors, and predictors are used interchangeably when explaining the findings.

### **4.3 Demographic and Circumstantial Risks: Childhood Pedestrian Mortality versus Burns and Drowning Mortality**

#### *4.3.1 Data source*

Pedestrian, burns and drowning mortality data for Johannesburg over the ten-year period in question was extracted from the NIMSS. The data included age groups, sex, population groups, and temporal information. In order to reveal missing data, a missing values assessment was conducted on the dataset to identify the pattern of the missing data. The mortality data for children, including the data for all children killed as pedestrians, or as a result of burns and drowning for Johannesburg from 2001 to 2010, was extracted from the NIMSS. The data included the victim's sex, population group, external cause of death (e.g. burns and drowning, day of death (Sunday, Monday, Tuesday, Wednesday, Thursday, Friday and Saturday), time of death (0h00–03h59, 04h00–07h59, 08h00–11h59, 12h00–15h59, 16h00–19h59 and 20h00–23h59); and month of death (January to December) of death.

### **4.4 Logistic Regression: Child Pedestrian Mortality versus Burns Mortality**

#### *4.4.1 Data analysis*

Logistic regression was used to determine the association, if any between a range of explanatory variables, and child pedestrian and burns mortality. The results for objective three were presented as follows: 1) predictors of child pedestrian, burn and drowning mortality; 2) logistic regression models that examined the *socio-demographic variables* associated with pedestrian versus burn mortality (Logistic Regression Analysis-Model 1), and a model that assessed temporal factors (Logistic Regression Analysis-Model 2).



For the predictors of child pedestrian, burns and drowning mortality, the circumstances and demographics of the occurrence of the mortality were examined using multivariate techniques based on the coded values of several variables which were descriptive of the type of mortality, i.e. pedestrian versus burn, and pedestrian versus drowning, age groups (0-4, 5-9, 10-14 years old); sex (male and female), population group (Indian, black, coloured and white), time of death (06h00-11h59, 13h00-18h59, 20h00-22h59 and 12h00-4h59), day of the week on which death occurred (Monday, Tuesday, Wednesday, Thursday and Friday), or weekend (Saturday and Sunday), holiday time (December, January, April, July and September) and non-holiday time (February, March, May, June, August and October).

For the socio-demographic variables associated with pedestrian versus burn mortality (Logistic Regression Analysis-Model 1), and for the model that assessed temporal factors (Logistic Regression Analysis-Model 2), an initial analysis was conducted to ensure that the underlying assumptions of logistic regression had not been violated. Initially, the association between type of mortality and these factors mentioned above was tested by means of a chi-square test and pseudo  $R^2$  (Nagelkerke value) to ascertain whether the model was indicative of being robust. The analysis focused on two discrete outcome categories, namely, child pedestrian mortality versus burns mortality, with the latter coded as the reference category. Two logistic regression analyses were computed. Each analysis examined a different model, but with all of the predictors introduced simultaneously into each model. The first model examined socio-demographic variables only, while the second model added temporal factors to the analysis. The model coefficients were exponentiated so that they could be interpreted as adjusted odds ratios (ORs), while 95% confidence intervals (CIs) were used to assess the magnitude and significance of the adjusted multivariate associations. A p-value of below 0.05 was considered

significant. The statistical analyses were performed using the IBM Statistical Package for the Social Sciences (SPSS Version 22).

#### **4.5 Logistic Regression: Child Pedestrian Mortality versus Drowning Mortality**

##### *4.5.1 Data source*

Mortality data for children as pedestrians, and as a result of drowning for Johannesburg from 2001 to 2010 was extracted from the NIMSS. The data included the victim's sex, population group, external cause of death (e.g. drowning) day of death (Sunday, Monday, Tuesday, Wednesday, Thursday, Friday and Saturday), time of death (0h00-03h59, 04h00-07h59, 08h00-11h59, 12h00-15h59, 16h00-19h59 and 20h00-23h59) and month of death (January to December).

##### *4.5.2 Data analysis*

Logistic regression was also used for this analysis to determine the association, if any between a range of explanatory variables, and child pedestrian and drowning mortality. For the socio-demographic variables associated with pedestrian versus burn mortality (Logistic Regression Analysis-Model 1), and for the model that assessed temporal factors (Logistic Regression Analysis-Model 2), an initial analysis was conducted to ensure that the underlying assumptions of logistic regression had not been violated. Initially, the association between type of mortality and these variables/factors mentioned above was tested by means of a chi-square test, and pseudo  $R^2$  (Nagelkerke value), to examine whether the model was suggestive of been robust. The analysis focused on two discrete outcome categories, namely, child pedestrian mortality versus drowning mortality, with the latter being coded as the reference category. Two logistic regression models were computed. The first model examined socio-demographic variables only, while the second model added temporal variables to the analysis. The model coefficients

were exponentiated so that they could be interpreted as adjusted odds ratios (ORs), while 95% confidence intervals (CIs) were used to assess the magnitude and significance of the adjusted multivariate associations. A *p*-value of below 0.05 was considered significant. The statistical analyses were performed using the IBM Statistical Package for the Social Sciences (SPSS Version 22).

## **4.6 Child Pedestrian Mortality and Neighbourhood Predictors**

### *4.6.1 Data sources*

Area-based data on Johannesburg was compiled using the Population Census of 2001 which had been conducted by StatsSA. This was the most recent data available at the time of the study. Data on child pedestrian mortality that had occurred during the period 2001 to 2010 was extracted from the NIMSS. The South Africa Census data for 2001 was used to extract descriptive information on the social and economic living circumstances in selected neighbourhoods in Johannesburg. The census data provides information at a number of levels, including local municipality, main place/suburb, sub-place and enumeration area. For the purposes of this thesis, area-based comparisons were conducted at the designated 'sub-place' level. A sub-place is a geographically specified area of which the boundaries approximate those of the official suburb boundaries provided by the local town councils, and the South African Surveyor General. The relevant census variables descriptive of the social and economic living circumstances of Johannesburg were used. These variables included, for example, the proportions of children under the age of fifteen, population groups, home ownership, proportions of female headed households, crowding and the child dependency proportions for each suburb (Census, 2001). The exclusion of 38.5% pedestrian mortality cases (413 out of 672 pedestrian cases) was used for the neighbourhood analysis. The 259 pedestrian mortality

cases outstanding from the analysis were the result of missing information on the suburb where the pedestrian deaths had occurred, since the data may not have been captured in detail.

#### *4.6.2 Unit of analysis*

The unit of analysis for the study consisted of residential areas in Johannesburg as based on the “sub-place” names provided by the South African Census data for 2001. At the time of the 2001 Census, Johannesburg had consisted of 684 demarcated sub-places. Of these areas, 132 comprised smaller habitable areas that were located within the larger residential areas. In view of the fact that the available pedestrian data was specific to the larger residential areas in the geographical unit, these 132 smaller zones were joined to make up 40 residential areas. Another 84 areas were excluded from the analysis because they comprised nature reserves, industrial parks, hospitals, universities, recreational areas and areas with populations of less than 200. The final number of residential areas included in the analyses was 508.

#### *4.6.3 Dependent variables*

The dependent variables for the purposes of this study included the total number of childhood pedestrian deaths, male and female child pedestrian deaths, child (0–4 years, 5–9 years and 10–14 years old), and black child pedestrian deaths for the Johannesburg municipal area from 2001 to 2010. The number of pedestrian deaths was pooled across a ten-year period to add stability to the estimates, and to ensure adequate pedestrian counts. Furthermore, following the procedures recommended by Osgood (2000), the number of pedestrian deaths was used rather than the rate of pedestrian deaths, because a considerable number of neighbourhoods had no childhood pedestrian deaths for the selected period. The dependent variables were drawn from the NIMSS database for the period 2001 to 2010.

#### 4.6.4 *Explanatory variables*

Based on both previous studies of pedestrian mortality in children from birth to 14 years, and on the availability of data for South Africa, 12 explanatory variables were compiled from the 2001 Census information (StatsSA, 2003) to reflect neighbourhood-level structural conditions, and also variations in socio-economic and resource deprivation, i.e. low household income, unemployment, low educational attainment and educational attendance, mode of transport (walking), family disruption (female-headed household and divorce), population turnover (residential mobility), housing density, informal dwelling and population group (black residents) (refer Table 4).

The measures of neighbourhood economic deprivation included in the study were poverty (the percentage of households earning less than R9600 annually), unemployment (the percentage of persons unemployed in the 15 to 64-year age group), and low educational attainment (the percentage of persons with less than Grade 12 and aged 25 years and older). These measures are similar to the measures which have been used in other injury, violence and criminology studies (Land, McCall, & Cohen, 1990; Pickett & Pearl, 2001; Van Hulst, Gauvin, Kestens, & Barnett, 2013; Swart, 2014; Wang & Arnold, 2008). An additional measure of educational attendance, namely, percentage of 5 to 14 year olds attending an educational institution, was included in order to capture the prevailing situation regarding young people's access to education in South Africa.

Two indicators of family disruption were included in the study, namely, percentage of female-headed households, and percentage of persons divorced aged 15 and older. These indicators have been used in prior research (Wang & Arnold, 2008). The last two measures were included as they were deemed to be relevant to the South African context, as a large proportion of

children in South Africa live in households without either parent (Jamie, Brey, Viviers, Lake, Pendlebury, & Smith 2011), and with some children also living in child-headed households (Richter & Desmond, 2008). In view of the fact that the South African census data precludes information on the number of children living with both, one or neither parent/s, and only provides information on the household members' relationship to the head of the household, the percentage of 0 to 19 year olds who were the children of the household head, was used in this study, as this measure provided an indication of the proportion of children who were living with at least one parent.

Since information on the land area size was unavailable, a measure of household density within each neighbourhood, namely, the number of residents per number of household rooms (excluding kitchen and bathroom) was used for the purposes of the study. Rapid urbanisation has taken the form of informal settlements in South Africa's cities, which typically consist of temporary dwellings with limited access to basic services such as water, electricity, sanitation and refuse removal. Accordingly, the percentage of households living in informal dwellings was included in the study as a measure of disadvantaged neighbourhood housing conditions.

Consistent with previous studies, residential mobility was measured by population turnover (percentage of persons aged five and over, and who have changed residences in the preceding five years (e.g. Kubrin, 2003; Wang & Arnold, 2008). Similar to other studies, the percentage of black individuals was used as a measure of the population group, while the percentage of non-citizenship in the population was used to capture ethnic composition (Kubrin, 2003; Land et al., 1990; Wang & Arnold, 2008). Reading, Haynes and Shenassa (2005) indicated that there is an expanding domain of work that examined the influences of neighbourhood characteristics

and area-based factors on childhood injury risk, also referred to as the so-called ecological or neighbourhood effects.

Current innovative research methods have enabled the disentangling of influences at the child, household, local neighbourhood and larger area levels, all of which contribute to determining and maintaining the social inequalities in childhood injury. It has been postulated that that differences between areas reflect the characteristics of the families who live in these areas. This in turn implies, that the elevated rates of childhood injury in disadvantaged areas may be the result of the prevalence of higher risks in poor families as compared to those in less poor families. These neighbourhood characteristics, and area – based factors have been described as compositional factors because they relate to the composition of the inhabitants of areas.

Similarly, area characteristics are termed contextual factors because, theoretically, they affect the entire neighbourhood, regardless of the social circumstances of the individual inhabitants. These contextual factors are especially significant in the case of unintentional injuries simply because such injuries occur in a *place* as well as to a *person*. In line with the systems approach to child pedestrian injury, the relevance of both the physical and social environments is integral to an understanding of the interplay between these environments as regards promoting safe childhood pedestrian mobility. Therefore, the neighbourhood variables chosen for the purposes of this study are consistent with studies which illustrated the effects of these variables on childhood injury (Haynes, Reading, & Gale, 2003; Kendrick, Mulvaney, Burton, & Watson, 2005; Reading et al., 2005).

**Table 4. Descriptions of the 12 explanatory variables used in the factor analysis**

<b>Variable</b>	<b>Description</b>	<b>Mean</b>	<b>Min</b>	<b>Max</b>
1. Low household income	Percentage of households earning less than R9600 annually	22.21	0.00	88.00
2. Unemployment	Percentage of persons unemployed in 15 to 64-year age group	13.57	0.00	58.30
3. Low educational attainment	Percentage of persons aged 25 years and older with less than Grade 12	49.13	11.50	94.12
4. Attendance at educational institution	Percentage of children aged 5 to 14 years attending educational institution	88.70	20.00	100.00
5. Mode of transport	Percentage of children aged 5 to 14 years who walk as their main mode of transport to school	28.06	0.00	100.00
6. Female-headed household	Percentage of female-headed households	37.12	0.00	71.43
7. Divorced	Percentage of persons divorced aged 15 and older	5.14	0.00	14.96
8. Household density	The number of residents per the number of household rooms (excluding kitchens and bathrooms)	.79	.32	3.81
9. Informal dwelling	Percentage of households living in informal dwellings	9.50	0.00	97.79
10. Population turnover	Percentage of persons aged five and over who have changed residences in the past five years	29.80	1.20	82.17
11. Black residents	Percentage of black residents	45.90	1.49	100.0
12. Non South African citizenship	Percentage of non-South African citizens	4.66	0.00	31.13

The fact that measures of socio-economic structural conditions tend to be highly correlated often creates the risk of multicollinearity in the statistical modelling process. This may in turn result in the projection of unreliable and unstable estimates of regression coefficients, thus rendering inferences about the relative contribution of each explanatory variable problematic. Land and colleagues (1990) recommended that, in order to reduce potential multicollinearity, factor analysis be applied to consolidate the explanatory variables into a smaller number of



factors. For the purposes of this study, the prevalence of the 12 contextual variables in all the residential areas (n = 508) was entered into an exploratory factor analysis (principal component), using orthogonal rotation (varimax with Kaiser normalisation).

A three factor model was derived. This model explained 72.54% of the cumulative variance (refer Table 5). These three neighbourhood factors then constituted the explanatory variables in the study.

**Table 5. Pattern matrix from factor analysis with factor loadings for explanatory variables**

Variables	Factor 1	Factor 2	Factor 3
Low household income	<b>.897</b>	.226	.038
Unemployment	<b>.873</b>	.346	-.070
Low educational attainment	<b>.825</b>	.344	-.109
Household density	<b>.815</b>	.135	-.141
Black residents	<b>.791</b>	.098	-.262
Informal dwellings	<b>.780</b>	.058	-.039
Mode of transport (walking)	<b>.721</b>	.476	.022
Attendance at educational institution	<b>-.707</b>	.099	.123
Divorced	-.527	-.147	<b>.610</b>
Population turnover	-.145	<b>-.823</b>	-.020
Non South African citizenship	-.108	<b>-.789</b>	.029
Female-headed household	.002	.064	<b>.923</b>

Note: Numbers in bold represent the highest loading of each variable on one factor

Factor 1 accounted for 51.8% of the variance between the three neighbourhood factors, and included percentage low educational attainment, percentage low household income, percentage unemployment, percentage informal dwellings, percentage unemployed, percentage attendance at educational institution, percentage household density and percentage black residents. Since these measures allude primarily to conditions of poverty and deprivation, factor 1 was labelled “concentrated disadvantage”. The variables captured in this factor were consistent with prior studies that showed similar loadings of economic measures, and percentage black in the population (Kubrin, 2003; Land et al., 1990), but also differed from studies in that female-headed households did not load on the factor (Strom & MacDonald, 2007; Wang & Arnold, 2008).

Factor 2, labelled “residential mobility”, accounted for 12.0% of the variance, and consisted of percentage non-South African citizens, and percentage population turnover.

Factor 3, labelled “female-headed households”, accounted for 8.7% of the variance, and consisted of the percentage of female-headed households, and the percentage of divorced individuals.

#### *4.6.5 Regression analysis adjusting for spatial autocorrelation*

Seven negative binomial regression models were computed to examine the relationship between neighbourhood characteristics and childhood pedestrian deaths. It was also necessary to use a negative binomial regression model in order to account for the highly skewed, and over dispersed count-level dependent variables (Osgood, 2000).

Since neighbourhoods tend to be spatially dependent as a result of processes such as dispersion and exposure, it is possible that the concentration of pedestrian deaths in one neighbourhood may influence the levels of pedestrian deaths in surrounding neighbourhoods (Morenoff, Sampson, & Raudenbush, 2001). From a statistical standpoint, it was important to initially test for spatial autocorrelation, that is, to ensure that the spatial processes that were operating and were not accounted for, may result in a multivariate regression analysis that provided misleading indications of significance, biased parameter estimates, and erroneous descriptions of fit (Messner, Anselin, Baller, Hawkins, Deane, & Tolnay, 1999).

A base map shape file for all the neighbourhoods in Johannesburg (based on the Municipal Demarcation Board City of the Johannesburg Metropolitan Municipality map, June 2009), and a data table consisting of the number of pedestrian deaths that had occurred in each of the neighbourhoods were joined in GeoDa<sup>TM2</sup> to create spatially lagged variables, and were tested for spatial autocorrelation (following the procedures outlined by Anselin, 2005).

A spatial weights matrix was then constructed based on rook's contiguity (neighbours were defined as sharing a common border). This was followed by the computation of spatially lagged variables for each of the dependent variables. Moran's I coefficient revealed a significant spatial association ( $p < .01$ ), and hence spatial lag variables were created based on the predicted values of the dependent variables (see Kubrin, 2003), which were then incorporated into each of the regression models to control for spatial autocorrelation.

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<sup>2</sup> GeoDa is a software package that provides several statistical applications for spatial data analysis. It may be downloaded from <https://geodacenter.asu.edu/>

Given that the analysis used pedestrian death counts, it was necessary to control for a variation in the size of the population at risk across neighbourhoods. This was achieved by adding the natural logarithm of the population at risk as an offset variable with a fixed coefficient of one to the regression models. This approach standardised the model by converting the counts of pedestrian deaths into the equivalent of a rate for each neighbourhood (Osgood, 2000).

The final regression model for childhood pedestrian deaths consisted of the following three neighbourhood factors, namely, concentrated disadvantage, residential mobility and female-headed household, with the spatial control and the natural logarithm of the population at risk (i.e. children 0–14 years), as an offset (refer Table 6). All the analyses were conducted using IBM SPSS Statistics for Windows, Version 20.0.

**Table 6. Child pedestrian deaths per neighbourhood in Johannesburg (2001–2010) (N = 413)**

	<b>Total</b>	<b>Mean</b>	<b>Standard</b>
<b>Deviation</b>			
All child pedestrian deaths	413	.81	2.963
Male child pedestrian deaths	254	.50	1.810
Female child pedestrian deaths	154	.30	1.225
Children of 0-4 yrs. pedestrian deaths	140	.28	1.089
Child of 5-9 yrs. pedestrian deaths	176	.35	1.378
Child of 10-14 yrs. pedestrian deaths	95	.19	.729
Black child pedestrian deaths	373	.73	2.807

## **5. ETHICAL APPROVAL**

Ethical permission to conduct the study was obtained from the Ethics Committee of the Department of Psychology, located in the College of Human Sciences at the University of South Africa (see Appendix 1 for ethics approval letter). The access to the NIMSS database, from which the data on childhood pedestrian deaths was drawn, was approved by the MRC – UNISA Violence, Injury and Peace Research Unit.

## **CHAPTER FIVE**

### **RESULTS**

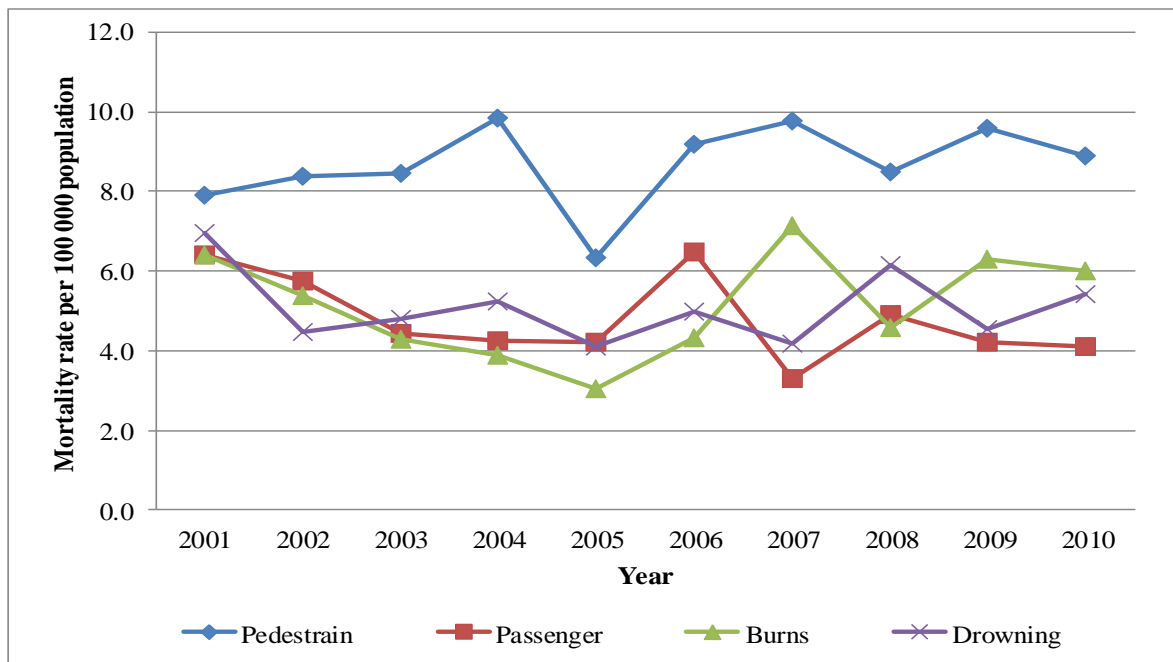
The overarching focus of the study was to describe and examine the distribution, patterns, circumstances and neighbourhood predictors of childhood pedestrian mortality from birth to 14 years in Johannesburg. This chapter focuses on research objectives one, two, three and four of the study, namely, to describe the incidence, demographics and circumstances of childhood pedestrian mortality in Johannesburg (2001–2010); to identify the demographic and circumstantial risks that differentiate childhood pedestrian mortality from childhood motor vehicle passenger mortality in Johannesburg (2001–2010); to identify the demographic and circumstantial risks that differentiate childhood pedestrian mortality from childhood burns and drowning mortality in Johannesburg (2001–2010), and to identify neighbourhood-level predictors of childhood pedestrian mortality in Johannesburg (2001–2010). The period of analysis was from 2001 to 2010.

The results for objective one are presented as follows: (1) overall incidence over time; (2) incidence by age, sex and population group; and (3) occurrence by time of day, weekday and month. The results for objective two are presented as follows: (1) predictors of child pedestrian and motor vehicle passenger mortality; (2) logistic regression model that examined the socio-demographic variables associated with pedestrian versus motor vehicle passenger mortality (Model 1), and a logistic regression model that assessed temporal factors (Model 2). The results for objective three are presented as follows: (1) descriptors of child pedestrian, burns and drowning mortality; (2) logistic regression model that examined the socio-demographic variables associated with pedestrian versus burn mortality (Model 1), and a logistic regression

model that assessed temporal factors (Model 2); and (3) logistic regression model that examined the socio-demographic variables associated with pedestrian versus drowning mortality (Model 1), and a logistic regression model that assessed temporal factors (Model 2). The results for objective four are presented as follows; (1) child pedestrian mortality per neighbourhood; and (2) negative binomial regression models that examined the relationship between neighbourhood predictors and child pedestrian mortality.

## **1. OVERALL INCIDENCE OF SELECTED CHILD INJURY MORTALITY**

It emerged that child pedestrian injuries were the leading cause of unintentional injury mortality for children aged 0 to 14 years old in every year from 2001 to 2010 (refer *Figure 9*, Table 7 below). During this ten-year period, childhood pedestrian deaths accounted for over 30% of all childhood unintentional injury deaths. When comparing the overall annual average cause specific mortality rates in children aged 0 to 14 years old, the rates for pedestrians (6.86 per 100 000 population, n = 756) exceeded that for motor vehicle passengers (4.81 per 100 000 population, n = 412), burns (5.13 per 100 000 population, n = 447), and drowning (5.08 per 100 000 population, n = 440).



*Figure 9.* Rates for child pedestrian, motor vehicle passenger, burns and drowning mortality in Johannesburg (2001–2010)

With respect to the annual average cause specific rates in children, pedestrians reflected the highest among the 5 to 9 year olds (11.02 per 100 000 population, n = 302) in relation to motor vehicle passengers (5.51 per 100 00 population, n = 121), burns (3.17 per 100 000 population, n = 87) and drowning (3.52 per 100 000 population, n = 96). Children 0 to 4 years old displayed the highest annual average for burns (9.17 per 100 000 population, n = 312), followed by drowning (8.51 per 100 000 population, n = 287), pedestrians (8.09 per 100 000 population, n = 276), and then motor vehicle passenger (5.22 per 100 000 population, n = 175). Lastly, among the 10 to 14 year olds, pedestrians also featured relatively prominently with an annual average rate of (7.01 per 100 000 population, n = 178), followed by motor vehicle passenger (4.59 per 100 000 population, n = 116), drowning (2.22 per 100 000 population, n = 66) and then burns (1.91 per 100 000 population, n = 48).



Pedestrians recorded the highest annual averages for all age groups from 2001 to 2010 in relation to motor vehicle passengers, burns and drowning with the exception of burns and drowning in the 0 to 4-year age group. Similar trends in cause specific mortality rates were also observed across the ten years. The results that follow focus on the incidence of child pedestrian mortality by age, sex and population group.

**Table 7. Mortality rates for child pedestrians, motor vehicle passengers, burns and drowning, Johannesburg (2001-2010) (N = 2055)**

		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010				Annual
Year																								Average
		Total	Rate /	Total	Rate /	Total	Rate /	Total	Rate /	Total	Rate /	Total	Rate /	Total	Rate /	Total	Rate /	Total	Rate /	Total	Rate /	Total	Rate /	100
		death	100 000	death	100 000	death	100 000	death	100 000	death	100 000	death	100 000	death	100 000	death	100 000	death	100 000	death	100 000	deaths	100	000 pop
		s	pop.	s	pop.	s	pop.	s	pop.	s	pop.	s	pop.	s	pop.	s	pop.	s	pop.	s	pop.			
0-4 years age group	Pedestrian	17	6.40	26	9.21	25	8.36	30	9.50	22	6.62	29	8.31	27	7.38	33	8.63	34	8.51	33	7.93	276	8.09	
	Passenger	16	6.02	17	6.02	29	6.35	16	5.07	12	3.61	25	7.16	15	4.10	20	5.23	23	5.76	12	2.88	175	5.22	
	Burns	30	11.29	29	10.27	24	8.03	20	6.33	20	6.02	28	8.02	45	12.30	29	7.58	40	10.02	47	11.30	312	9.17	
	Drowning	29	10.92	25	8.85	26	8.69	31	9.82	23	6.92	26	7.45	27	7.38	36	9.41	24	6.01	40	9.62	287	8.51	
5-9 years age group	Pedestrian	23	9.79	25	10.27	27	10.73	32	12.31	19	7.08	39	14.09	37	12.98	26	8.86	33	10.94	41	13.22	302	11.02	
	Passenger	13	5.53	8	7.40	10	3.97	9	3.46	13	4.84	17	6.14	8	2.81	12	4.09	10	3.31	11	3.55	121	4.51	
	Burns	10	4.26	8	3.29	5	1.99	6	2.31	4	1.49	6	2.17	12	4.21	12	4.09	14	4.64	10	3.22	87	3.17	
	Drowning	14	5.96	6	2.47	6	2.38	5	1.92	9	3.35	11	3.97	7	2.46	15	5.11	15	4.97	8	2.58	96	3.52	
10-14 years age group	Pedestrian	18	7.73	13	5.48	15	6.2	19	7.71	13	5.18	13	5.09	25	9.62	21	7.95	26	9.68	15	5.49	178	7.01	
	Passenger	18	7.73	9	3.79	6	2.48	10	4.06	11	4.39	15	5.88	7	2.69	14	5.3	8	2.98	18	6.59	116	4.59	
	Burns	7	3.00	4	1.68	5	2.07	6	2.44	2	0.8	4	1.57	8	3.08	2	0.76	7	2.61	3	1.10	48	1.91	
	Drowning	18	3.43	3	1.26	6	2.48	7	2.84	3	1.2	7	2.74	4	1.54	7	2.65	5	1.86	6	2.20	66	2.22	
0-14 years age group	Pedestrian	58	7.91	64	8.39	67	8.45	81	9.85	54	6.34	81	9.19	89	9.77	80	8.51	93	9.59	89	8.91	756	6.86	
	Passenger	47	6.41	44	5.77	35	4.42	35	4.26	36	4.23	57	6.47	30	3.29	46	4.89	41	4.23	41	4.10	412	4.81	
	Burns	47	6.41	41	5.37	34	4.29	32	3.89	26	3.05	38	4.31	65	7.14	43	4.57	61	6.29	60	6.00	447	5.13	
	Drowning	52	6.95	34	4.46	38	4.79	43	5.23	35	4.11	44	4.99	38	4.17	58	6.17	44	4.54	54	5.40	440	5.08	

## **2. AGE-SPECIFIC MORTALITY RATES FOR CHILD PEDESTRIANS**

Age-specific annual injury death rates among children aged 0 to 14 years old across the ten-year period was visibly the highest for the 5 to 9 year olds at (11.02 per 100 000 population, n = 302), followed by the 0 to 4 year olds at (8.09 per 100 000 population, n = 276) and, lastly, the 10 to 14 year age group at (7.01 per 100 000 population, n = 178). The annual average rate for children aged 0 to 14 years old was 6.86 per 100 000 population (n = 756).

When comparing trends for the different age groups for each year over the ten-year period, it was clear that the 5 to 9-year age group consistently reflected higher rates than both the 0 to 4 year olds and 10 to 14 year olds. Children 0 to 4 years old and 10 to 14 years old also exhibited varying fluctuations across the ten years. The results conclusively revealed that the age-specific mortality rates were the highest in the 5 to 9 age group, followed by the 0 to 4 year olds and the 10 to 14 year olds respectively.

Overall age specific trend rates for all age categories were relatively stable across the ten years (see Table 8 below). The findings discussed below pertain to the sex-specific mortality rates for children in the 0 to 14-year age group.

**Table 8. Age-specific mortality rates for child pedestrians, Johannesburg (2001–2010) (N = 756)**

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010			
	Rate/ 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Total deaths	Annual Average rate / 100 000 pop	
Age  Group	0-4 years	6.40	9.21	9.50	6.62	8.31	7.38	8.63	8.51	7.93	6.40	276	7.89
	5-9 years	9.79	10.27	12.31	7.08	14.09	12.98	8.86	10.94	13.22	9.79	302	10.93
	10-14 years	7.73	5.48	7.71	5.18	5.09	9.62	7.95	9.68	5.49	7.73	163	7.17
	0-14 years	7.91	8.39	9.85	6.34	9.19	9.77	8.51	9.59	8.91	7.91	756	8.64

### 3. SEX-SPECIFIC MORTALITY RATES FOR CHILD PEDESTRIANS

The findings indicate that male children aged 0 to 14 years old are more predisposed than females to a pedestrian injury death compared to their female counterparts. Males reflected a mortality rate of (32.31 per 100 000 population, while the females recorded a rate of 19.20 per 100 000 population (see Table 9 below).

It is worth noting that males in the 5 to 9-year-old group were more vulnerable in terms of the overall average pedestrian mortality rate of (13.86 per 100 000 population) as compared to the females at 7.79 per 100 000 population). A similar trend was observed for males in the 0 to 4 - age group (9.87 per 100 000 population) when compared to the female average of 6.22 per 100 000 population). In the 10 to 14-year age group, males also recorded a higher average rate of 8.59 per 100 000 as compared to the female average rate of 5.18 per 100 000 population).

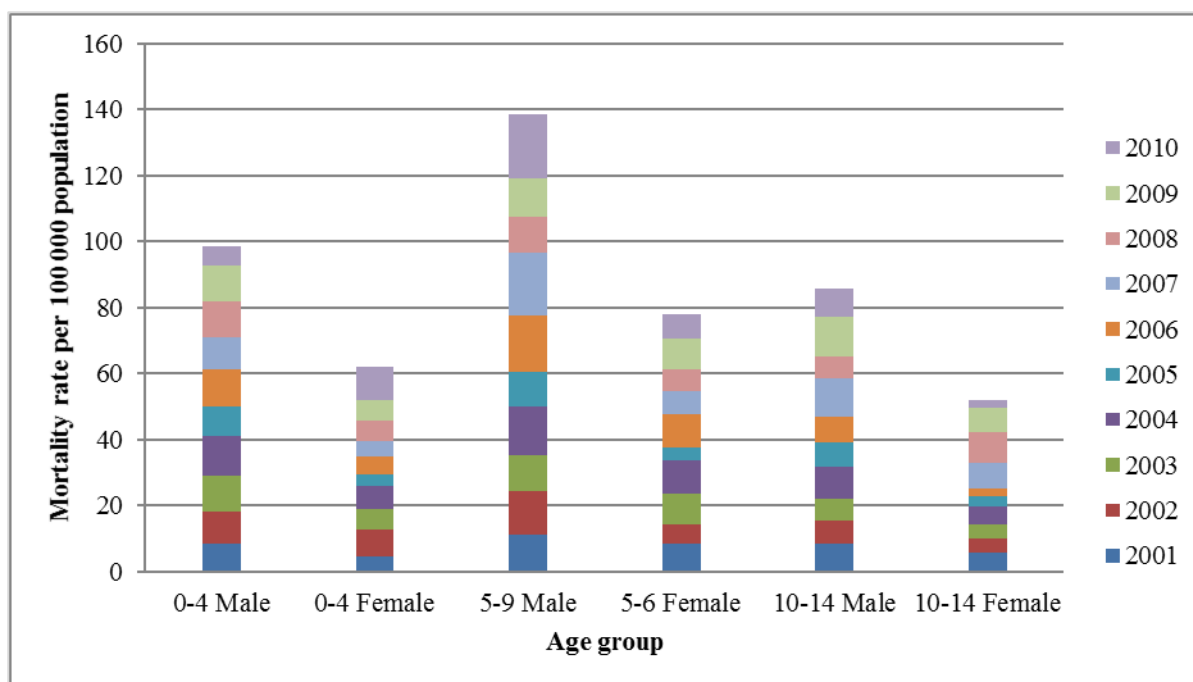


Figure 10. Sex-specific rates for child pedestrian mortality, Johannesburg (2001-2010)

**Table 9. Child pedestrian mortality by sex and age (N = 747)**

Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total Deaths	Annual Average rate / 100 000 pop
		Rate	Rate /	Rate /	Rate /	Rate/	Rate/	Rate/	Rate/	Rate /	Rate /		
		/ 100	100	100	100	100	100	100	100	100	100		
		000	000	000	000	000	000	000	000	000	000		
		pop	pop	pop	pop	pop	pop	pop	pop	pop	pop		
<b>0-4 age</b>	<b>Male</b>	8.32	9.94	10.7	12.01	8.99	11.40	9.78	10.89	10.92	5.71	168	9.87
<b>group</b>	<b>Female</b>	4.49	8.47	6.01	6.97	3.62	5.17	4.94	6.31	6.06	10.19	107	6.22
<b>5-9 age</b>	<b>Male</b>	11.09	13.17	11.13	14.60	10.41	17.30	18.88	10.86	11.87	19.24	191	13.86
<b>group</b>	<b>Female</b>	8.48	5.74	9.52	10.00	3.73	10.14	7.037	6.84	9.32	7.13	106	7.79
<b>10-14 age</b>	<b>Male</b>	8.67	6.79	6.65	9.78	7.19	7.84	11.54	6.80	11.87	8.74	109	8.59
<b>group</b>	<b>Female</b>	5.95	4.17	4.10	5.65	3.18	2.34	7.70	9.09	7.46	2.20	66	5.18
<b>0-14 age</b>	<b>Male</b>	28.08	29.9	28.48	36.39	26.59	36.54	40.2	28.55	34.66	33.69	468	32.31
<b>group</b>	<b>Female</b>	18.92	18.38	19.63	22.62	10.53	17.65	19.67	22.24	22.84	19.52	279	19.20

In Figure 10 above, each coloured band represents the rate per 100 000 population for each specific age group, and sex for each year across a ten year period. Overall, for all the age groups and sex across the ten years, the annual average childhood pedestrian mortality rate for males exceeded that of females.

#### 4. POPULATION-SPECIFIC RATES FOR CHILD PEDESTRIANS

In comparison to the other population groups, black children consistently showed higher rates of pedestrian mortality over the ten years. Among the various population groups, black children reflected the highest average childhood pedestrian mortality rate of 10.22 per 100 000 population, nearly double the rate of coloureds at 5.19 per 100 000 population, and three times the rate of Indians at 3.68 per 100 000 population (see Table 10 below). Both white children (1.64 per 100 000 population) and Indian children (3.68 per 100 000 population) reflected significantly lower rates for childhood pedestrian mortality compared to the children in the

other population groups. The following results pertain to the circumstances of child pedestrian mortality as per time of day, day of the week and month.

**Table 10. Population-specific rates for child pedestrian mortality, Johannesburg (2001-2010) (N = 751)**

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010		
	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Rate / 100 000 pop	Total Deaths	Annual Average rate / 100 000 pop
<b>Indian</b>	3.37	3.17	2.99	2.83	2.69	2.56	7.34	4.68	4.49	2.15	14	3.68
<b>Black</b>	9.37	8.77	10.52	11.34	7.56	11.04	11.33	9.70	11.06	10.94	690	10.22
<b>Coloured</b>	5.21	13.67	1.68	6.63	3.27	3.22	7.93	6.25	4.62	0.00	32	5.19
<b>White</b>	2.19	2.19	0.00	4.37	0.00	1.09	0.00	2.18	3.27	1.09	15	1.64

## **5. CIRCUMSTANCES OF CHILD PEDESTRIAN MORTALITY:**

### **OCCURRENCE BY TIME OF DAY, DAY OF THE WEEK AND MONTH**

#### **5.1 Child Pedestrian Mortality by Time**

Overall, it would appear that children from all the age groups were the most vulnerable to pedestrian mortality from 16h00 to 19h59, and were also susceptible to pedestrian mortality from 12h00 until 19h59 (see Figure 11 below). It was visible that children from all age groups were more predisposed to a pedestrian injury death during the following times: 16h00 to 19h59, followed by 12h00 to 15h59, 0h00 to 11h59 and, lastly, from 00h00 to 03h59. The proportion of pedestrian injury deaths during the other time periods was noticeably less among all age groups. The results that follow pertain to child pedestrian mortality by day of the week.

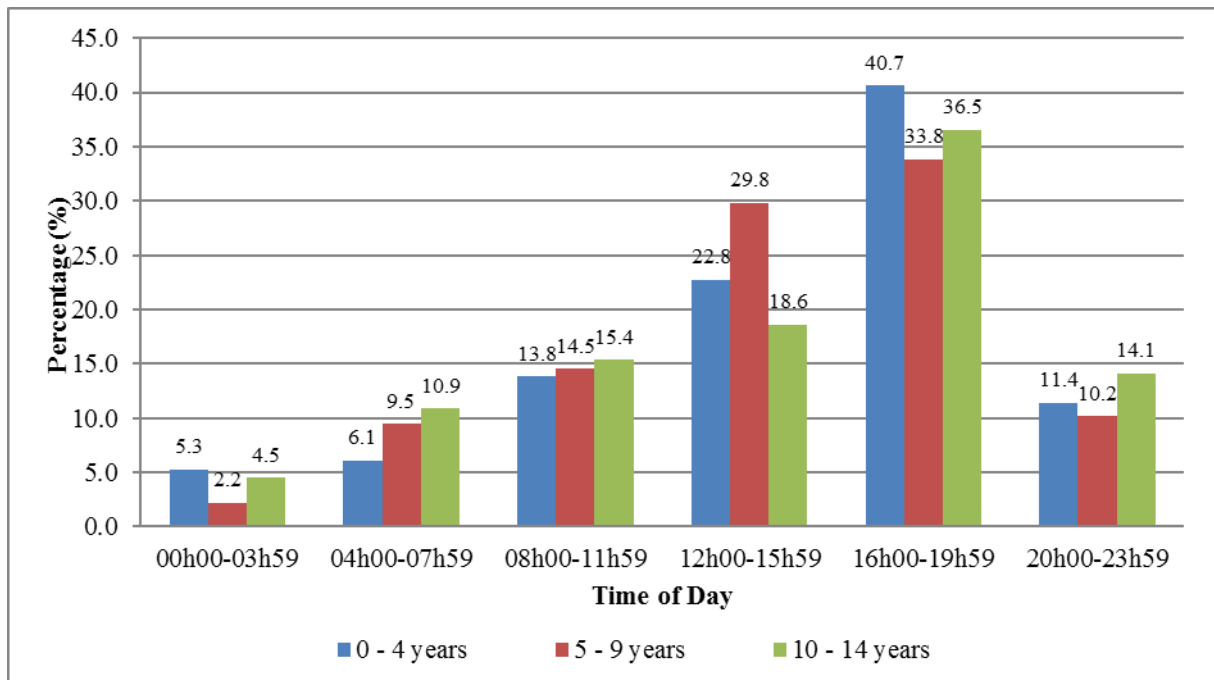


Figure 11. Distribution of child pedestrian mortality by time, Johannesburg (2001–2010)

## 5.2 Child Pedestrian Mortality by Day of the Week

The study revealed that there is a higher occurrence of childhood pedestrian injury deaths among all age groups over the weekend (Saturday–Sunday). Children aged 5 to 9 years old were the most vulnerable to a pedestrian mortality on a Sunday (26%), and to a lesser extent, children 0 to 4 years old (20%) and 10 to 14 years old (20%). However, children 0 – 4 years old reflected higher frequencies of pedestrian mortality on a Saturday (22%) (see Figure 12 below). The results that follow indicate child pedestrian mortality by month.



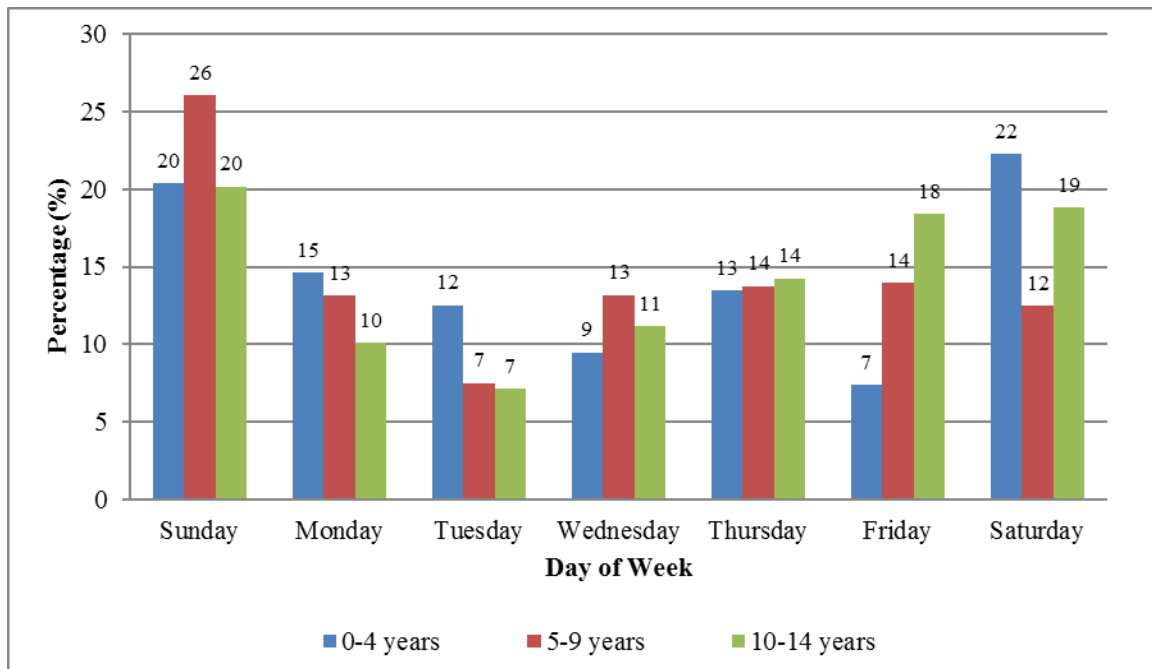


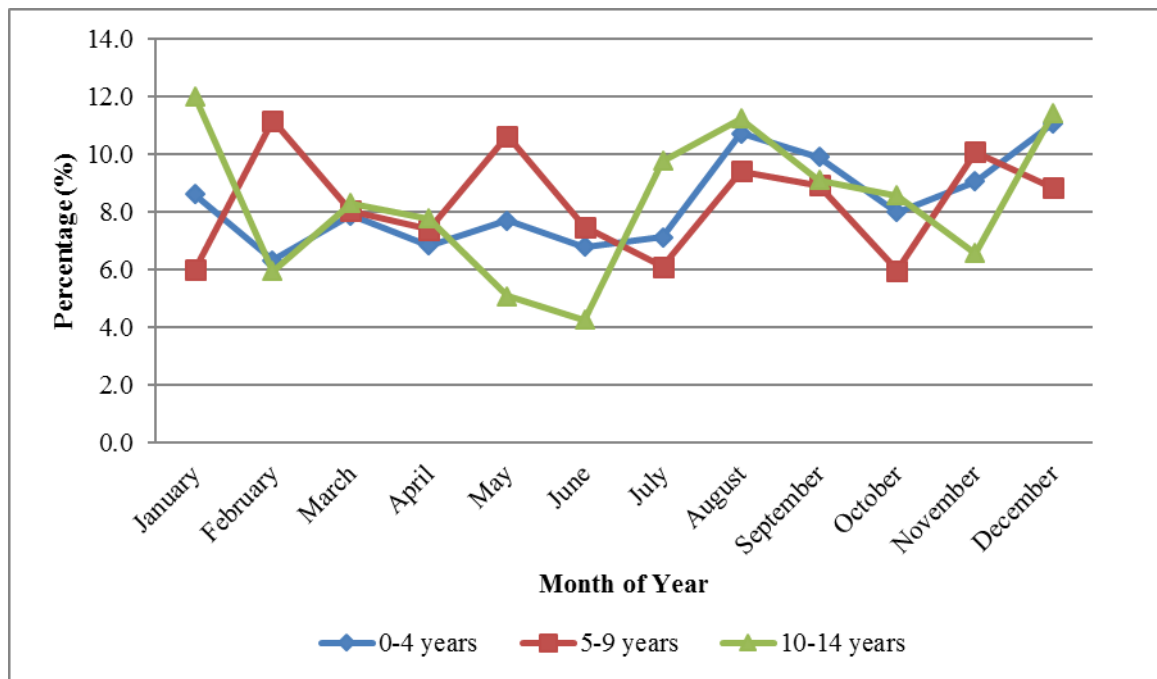
Figure 6. Distribution of child pedestrian mortality by day, Johannesburg (2001–2010)

### 5.3 Child Pedestrian Mortality by Month

In general, the study revealed that children of all age groups are vulnerable to a pedestrian mortality throughout the year. However, child pedestrian mortality for all age groups was higher in the months of December, November, September, August and January, and lower in the months of February, May and July. Pedestrian injury deaths showed noticeable fluctuations in frequencies in children from all age groups for the different months of the year.

For children aged 0 to 4 years the months of January (9%), August (11%), September (10%), November (9%) and December (11%) recorded higher deaths, while in the 5 to 9 year age group, the months of February (11%), May (11%), August (9%), September (9%), November (10%) and December (9%) indicated a higher of percentage deaths, and for children aged 10 to 14 years old, the months of January (12%), December (11%), August, (11%) and July (10%) recorded higher percentages of death (see Figure 13 below).

In general, the study showed that higher pedestrian deaths were recorded for all age groups during the school holidays, namely, December, January, April, July, and September although, during the other months of the year, children were also vulnerable but to a lesser extent.



*Figure 7.* Distribution of child pedestrian mortality by month, Johannesburg (2001–2010)

In brief, with regard to the first research objective, child pedestrian injuries were found to be the leading cause of unintentional injury mortality for children aged 0 to 14 years old every year from 2001 to 2010. Overall, across all age groups, children aged 5 to 9 years old exhibited higher rates of pedestrian mortality compared to children 0 to 4 years old and 10 to 14 years old. The average childhood pedestrian mortality rate for males exceeded that of females.

Black children consistently showed higher rates of pedestrian mortality compared to children from the other population groups. The occurrence of pedestrian mortality appeared to be higher over weekends, from 16h00 to 19h59 and was especially high during the school holidays, and

to a lesser extent, during the other months of the year. The findings that follow pertain to the second research objective, i.e. the demographic and circumstantial risks of childhood pedestrian versus motor vehicle passenger mortality.

## **6. DEMOGRAPHIC AND CIRCUMSTANTIAL RISKS: CHILDHOOD**

### **PEDESTRIAN VERSUS MOTOR VEHICLE PASSENGER MORTALITY**

The method used to realize this objective involved multivariate logistic regression, that enables the researcher to predict categorical outcomes based on predictor variables. The dependant variable for this logistic regression analysis was childhood pedestrian mortality, and was assessed on a dichotomous scale. The two categories of the predictor (independent) variables, namely, socio-demographic and temporal correlates were considered in terms of predicting the following discrete outcome: child pedestrian versus child motor vehicle passenger mortality.

Table 10 below presents a summary of the frequency distribution of the socio-demographic and temporal characteristics of pedestrian, and motor vehicle passenger mortality in Johannesburg. There was a total of 1011 child pedestrian and motor vehicle passenger injury deaths during the period 2001 to 2010. It is worth noting that pedestrians accounted for the majority (66.4%, n = 671) of these deaths as opposed to motor vehicle passengers (33.6%, n = 340).

A disproportionately higher percentage of male injury deaths (63%, n = 671) were recorded compared to females (37%, n = 371), while for the population groups, black children represented the highest traffic injury mortality (87%, n = 880) followed by coloured children (5.3%, n = 54), white children (4.8%, n = 49) and Indian children (2.8%, n = 28). The 0 to 4-year age group recorded the highest mortality for both pedestrian and motor vehicle passengers

(38.1%, n = 385), followed by the 5 to 9 year olds (37.4%, n = 378), and lastly, the 10 to 14 year olds (24.5%, n = 248).

With reference to the time of day, pedestrian and motor vehicle passenger mortality peaked between 13h00 and 19h00 (51.1%, n = 517), followed by 06h00 and 12h00 (24.9%, n = 252) and, lastly, from 20h00 and 05h00 (23.9%, n = 242). Weekdays (Monday to Friday) reflected a higher percentage for both pedestrians and motor vehicle passengers (63.6%, n = 643) as compared to the weekend (Saturday and Sunday (36.4%, n = 368).

Higher frequencies of childhood traffic injury deaths were recorded during the holiday months of December, January, April, July and September (41.8%, n = 423), with a lower percentage in the non-holiday months of February, March, May, June, August and October (58.2%, n = 588) (see Table 11 below).

**Table 11. Description of socio-demographic and temporal characteristics of pedestrian and motor vehicle passenger mortality, Johannesburg (2001–2010) (N = 1011)**

	Frequency (N)	Valid Percentage (%)
<b>Pedestrians</b>	<b>671</b>	<b>66.4%</b>
<b>Passengers</b>	<b>340</b>	<b>33.6%</b>
0–4	385	38.1%
5–9	378	37.4%
10–14	248	24.5%
Sex		
Male	637	63%
Female	374	37%
Population Group		
Indian	28	2.8
Black	880	87%
Coloured	54	5.3
White	49	4.8
06h00–12h00	252	24.9%
13h00–19h00	517	51.1%
20h00–05h00	242	23.9%
Weekday (Monday– Friday)	643	63.6%
Weekend (Saturday– Sunday)	368	36.4%
Holiday	423	41.8%
Non-holiday	588	58.2%

The following findings reflect the logistic regression models for child pedestrian versus motor vehicle passenger mortality for Johannesburg for the period 2001 to 2010.

Logistic regression was used as an analytical approach to predicting a dichotomous outcome. The logistic regression model permitted an analytical description of the predictor (independent) variables that differentiated child pedestrian from motor vehicle passenger mortality. A variety of logistic regressions were performed to assess the independent associations between each of the socio-demographic and temporal variables, and the risk for child pedestrian mortality relative to that of motor vehicle passengers.

The findings are discussed in relation to two logistic regression models. The first logistic regression model examined only the socio-demographic variables associated with child pedestrian mortality (refer Model 1), while the second logistic regression model assessed and included both socio-demographic and temporal factors (refer Model 2).

### **6.1 Logistic Regression Model 1: Analysis of Socio-Demographic Variables**

The results derived from logistic regression Model 1 indicated that, with the inclusion of the socio – demographic variables of sex, age and population groups, only the population group was significant for child pedestrian mortality relative to that of motor vehicle passengers, while sex and age group were not significant. Thus, the findings showed that children of both sexes, and from any age group were both equally likely to die from a pedestrian mortality when compared to motor vehicle passengers (refer Table 12 below).

When examining the socio-demographic variables, it emerged that children associated with the coloured and black population groups were more vulnerable of dying from a child pedestrian death. The analyses revealed that, compared to a white child dying from a pedestrian mortality as opposed to being a motor vehicle passenger, a coloured child was six times more vulnerable [OR (95% CI): 6.701 (3.438 – 13.060),  $p < 0.001$ ], while a black child was approximately three

and half times more vulnerable [OR (95% CI): 3.582 (1.527 – 8.401),  $p < 0.003$ ], and an Indian child three times more vulnerable [OR (95% CI): 3.328 (1.216 – 9.104),  $p < 0.019$ ]. This implies that, when compared with children from all the other population groups, the likelihood of a white child dying in a pedestrian mortality was significantly lower relative to motor vehicle passenger mortality (refer Table 12, Model 1).

When the socio-demographic variables of sex, age and population group were included in the analysis, this model explained indicatively a pseudo  $R^2$  (Nagelkerke) of 6.3% of the variance in the dependent variable. The logistic regression model was statistically significant (chi square = 47.238,  $p = 0.000$ ) (refer Table 12).

## **6.2 Logistic Regression Model 2: Analysis of Temporal Variables**

The independent variable, time of day, emerged as a significant predictor of pedestrian mortality, with the results indicating that children are more vulnerable during the mornings and the afternoons, compared to at night, for a pedestrian mortality relative to motor vehicle passenger mortality. Children were also equally at risk during any day of the week, including weekends, and during holidays compared to non-holidays as pedestrians relative to motor vehicle passengers.

When the temporal variables of time of day, day of the week and holiday and non-holiday were included in the model, with respect to the variable time, the findings showed that children were twice to three times more likely to die in the afternoon compared to other times of the day [OR (95% CI): 2.994 (2.149 – 4.172),  $p < 0.001$ ], and almost twice more likely [OR (95% CI): 1.883 (1.296 – 2.737),  $p < 0.000$ ] to die during the day as opposed to the night as a pedestrians, relative to motor vehicle passengers (refer Table 12, Model 2) .

In addition, children were equally likely to die as pedestrians rather than motor vehicle passengers both on weekdays and over weekends. Children were also vulnerable to pedestrian mortality irrespective of whether it was during the holiday months, or non-holiday months, relative to motor vehicle passengers. The addition of the temporal variables generated a pseudo  $R^2$  (Nagelkerke) of 12.5% of the variance in the dependent variable. The overall regression model was statistically significant (chi square = 95.125,  $p = .000$ ) (see Table 12, Model 2).



**Table 12. Logistic regression analyses for child pedestrian versus motor vehicle passenger mortality, Johannesburg (2001–2010)**

Independent Variable	Model 1				Model 2			
	Sig.	Odds Ratio	95% CI for Exp(B)		Sig.	Odds Ratio	95% CI for Exp(B)	
			LB	UB			LB	UB
Socio-demographic Variable								
Sex								
Male	.925	.987	.747	1.303	.792	.962	.723	1.281
Female	0 <sup>b</sup>							
Age								
0–4 years	.786	1.048	.745	1.474	.986	1.003	.706	1.426
5–9 years	.070	1.381	.974	1.959	.201	1.265	.882	1.816
10–14 years	0 <sup>b</sup>	.	.	0	.	.	.	.
Population Group								
Indian	0.40	2.787	1.048	7.414	.019	3.328	1.216	9.104
Coloured	.060	0.040	3.143	11.68	.000*	6.701	3.438	13.060
Black	.004	3.360	1.459	7.735	.003*	3.582	1.527	8.401
White	0 <sup>b</sup>	.	.	0	.		.	.
Temporal Variables								
Time of Day								
05h00–12h59	.	.	...		.001*	1.883	1.296	2.737
13h00–19h59	.	.	...		.000*	2.994	2.149	4.172
20h00–23h59					.	.	.	.
00h00–4h59					.	.	.	.
Day of Week								
Weekday	.	.	....		.064	1.308	.984	1.739
Weekend	.	.	....		.	.	.	.
Time of Year								
Vacation	.	.	...		.596	1.079	.815	1.427
Non-vacation	.	.	...		.		.	.

<sup>a</sup>. The reference category is: Passengers

<sup>b</sup>.  $X^2$ Chi-Sq. (Model 1) – 47.238; c. pseudo  $R^2$  (Nagelkerke) – 0.63 (6.3%); d.  $p$  – 0.000

<sup>c</sup>.  $X^2$ Chi-Sq. (Model 2) – 95.125; f. pseudo  $R^2$  (Nagelkerke) – 0.125 (12.5%); g.  $p$  – 0.000

Note. \* $p$  < .05; Exp (B) = odds ratio; CI = confidence interval; LL = lower limit; UL = upper limit

In summarising the findings relating to the second research objective, it was clear that, when the socio-demographic variables of sex, population and age group were included in the logistic regression model, the findings were significant only for children from the coloured and black population groups, when comparing child pedestrian mortality relative to motor vehicle

passenger mortality (see Table 12, Model 1). However, when both the socio-demographic and temporal predictors / variables were included in the logistic regression model, the findings were also only significant for children from the coloured and black population groups (see Table 12, Model 2).

Substantively, there were no significant differences for both age and sex in terms of childhood pedestrian mortality versus motor vehicle passenger mortality. In other words, children of either sex or belonging to any age group are both vulnerable to suffering a pedestrian mortality compared to a motor vehicle passenger death. Children are also more vulnerable to pedestrian deaths during the afternoon and morning as opposed to the night as opposed to motor vehicle passengers.

However, more importantly, irrespective of the age and sex of the child, and whether it is a weekday or weekend, holiday or non-holiday, a child is more vulnerable to a fatal pedestrian injury as opposed to motor vehicle passenger injury. The discussions below focuses on the third research objective that relates to the demographic and circumstantial risks for childhood pedestrian versus burns and drowning mortality.

## **7. DEMOGRAPHIC AND CIRCUMSTANTIAL RISKS: CHILDHOOD PEDESTRIAN VERSUS BURNS AND DROWNING MORTALITY**

In attempting to assess this objective, the study used logistic regression models to predict the categorical (dependant variable) outcomes based on the independent variables. The dependant variable for the purposes of this logistic regression analyses was childhood pedestrian mortality. This was assessed on a dichotomous scale, where the two categories of the predictor (independent) variables namely; socio-demographic and temporal factors / correlates, were

considered in terms of predicting the following discrete outcomes, namely, child pedestrian mortality versus burns, and child pedestrian mortality versus drowning.

Table 13 below presents a summary of the frequency distribution of all the socio-demographic and temporal characteristics of pedestrian, burns and drowning mortality for Johannesburg for the period 2001 to 2010. The total number of combined deaths for pedestrian injuries, burns and drowning injury was 1442. Childhood pedestrian mortality was notably the highest (46.5%, n = 671), followed by drowning (27.1%, n = 391) and then burns (26.4%, n = 380).

Males were disproportionately represented in the pedestrian, burns and drowning deaths combined (63.8%, n = 920), while children in the black population group reflected a higher frequency for all unintentional injury deaths (89.3%, n = 1287) compared to the other population groups. Children aged 0 to 4 years old exhibited the highest mortality for the combined unintentional injury deaths, (53.3%, n = 769), followed by the 5 to 9 year olds (29.6%, n = 427), and lastly, the age group 10 to 14 years old (17.1%, n = 246).

In general, with regards to of time of day, the study showed that children are more susceptible to these unintentional injury deaths during the afternoons from 13h00 to 19h00 (51.4%, n = 741), then during the mornings from 06h00 to 12h00 (24.5%, n = 354) and, lastly, during the night from 20h00–05h00 24.1%, n = 347). Children are also more at high risk to these unintentional injury deaths on weekdays – Monday to Friday (66.4%, n = 958), rather than over the weekends – Saturdays and Sundays (33.6%, n = 484). In addition, more pedestrian, burns and drowning deaths combined occurred during the non-holiday months (56.4%, n = 813) as opposed to the holiday months (43.6%, n = 629) (see Table 13 below).

**Table 13. Description of the socio-demographic and temporal characteristics of pedestrian, burns and drowning mortality, Johannesburg (2001–2010) (N = 1442)**

		<b>N</b>	<b>Marginal Percentage</b>
<b>Pedestrian</b>		671	46.5%
<b>Burns</b>		380	26.4%
<b>Drowning</b>		391	27.1%
<b>Sex</b>	Male	920	63.8%
	Female	522	36.2%
<b>Population Group</b>	Indian	33	2.3%
	Black	1287	89.3%
	Coloured	60	4.2%
	White	62	4.3%
<b>Age Group</b>	0-4 years	769	53.3%
	5-9 years	427	29.6%
	10-14 years	246	17.1%
<b>Time of Day</b>	06h00 to 12h00	354	24.5%
	13h00 to 19h00	741	51.4%
	20h00 to 05h00	347	24.1%
<b>Weekday/Weekend</b>	Monday–Friday	958	66.4%
	Saturday and Sunday	484	33.6%
<b>Holiday Period</b>	Holiday	629	43.6%
	Non-Holiday	813	56.4%
<b>Total</b>		1442	100.0%

## 7.1 Child Pedestrian versus Burns Mortality

For the purposes of this analysis, logistic regression models were used as an analytical approach to predicting dichotomous outcomes. The logistic regression models allowed for analytical

descriptions of the predictor (independent) variables that differentiated child pedestrian from burn mortality. A variety of logistic regressions were computed to assess the independent associations between each of the socio-demographic variables (refer Table 14 below, Model 1) and the temporal factors (refer Table 14 below, Model 2), and the risk for pedestrian mortality relative to burns.

#### *7.1.1 Logistic Regression Model 1: Analysis of socio-demographic variables*

The results derived from logistic regression Model 1 indicated that, with the inclusion of the socio – demographic variables of sex, age and population groups, only age was a significant predictor for child pedestrian mortality relative to burns mortality. Children 0 to 4 years old did reflect a significant value for child pedestrian mortality [OR (95% CI): .244 (.170 – .365),  $p < 0.000$ ] and are therefore 75% less likely than teenagers to die as a result of a pedestrian death compared to a non-traffic death, i.e. children in this age group are more likely to die from a burn than a pedestrian mortality (refer Table 14 below, Model 1).

There was no difference between the children from the middle to older age groups dying from a pedestrian mortality relative to a burn. When the socio-demographic variables of sex, age and population group were included, the logistic regression analysis in Model 1 indicated a pseudo  $R^2$  (Nagelkerke) of 15.3% of the variance in the dependent variable. The logistic regression model was statistically significant (Chi – squared = 208.889,  $p = .000$ ) (refer Table 14).

#### *7.1.2 Logistic Regression Model 2: Analysis of temporal variables*

After the addition of the temporal variables to the logistic regression model, the findings showed that time of day was a significant predictor for child pedestrian injury deaths relative to burns. When compared to dying from a pedestrian injury relative to a burn, the study found

that children are four times more susceptible from midday to early evening [OR (95% CI): 4.311 (3.112 – 8.971),  $p < 0.000$ ], and two and a half times more likely to die from the early morning to midday [OR (95% CI): 2.604 (1.806 – 3.756),  $p < 0.000$ ] (refer Table 14, Model 2).

In addition, children are equally as likely to die as pedestrians on a weekday, and or over weekend relative to burns. A child is also susceptible to a pedestrian death throughout the year, irrespective of whether it is holidays or non-holidays relative to burns. The addition of the temporal variables to the logistic regression model generated a pseudo  $R^2$  (Nagelkerke) of 23.0%, of the variance in the dependent variable. The overall logistic regression model was statistically significant (chi-square = 325.575,  $p = .000$ ) (see Table 14 below).

**Table 14. Logistic regression analysis of child pedestrian mortality versus burns mortality, Johannesburg (2001-2010)**

Independent Variable	Model 1				Model 2			
	Sig.	Odds Ratio	95% CI for Exp(B)		Sig.	Odds Ratio	95% CI for Exp(B)	
			LB	UB			LB	UB
Socio-Demographic Variable								
Sex								
Male	.382	1.128	.861	1.478	.277	1.168	.883	1.546
Female	0 <sup>b</sup>							
Age								
0–4 years	.000*	.244	.170	0.365	.000*	.250	.168	0.371
5–9 years	.704	1.087	.706	1.675	.873	1.037	.663	1.621
10–14 years	0 <sup>b</sup>	.	.	0	.	.	.	.
Population Group								
Indian	.339	.510	.129	2.024	.382	.535	.131	2.176
Coloured	.117	.430	.150	1.235	.104	.410	.140	1.200
Black	.375	.569	.164	1.198	.238	.465	.130	1.660
White	0 <sup>b</sup>	.	.	0	.	.	.	.
Temporal Variables								
Time of Day								
05h00–12h59	.	.	...		.000*	2.604	1.806	3.756
13h00–19h59	.	.	...		.000*	4.311	3.112	5.971
20h00–23h59					.	.	.	.
00h00–4h59					.	.	.	.
Day of the Week								
Weekday	.	.	....		.333	.866	.647	1.159
Weekend	.	.	....		.	.	.	.
Time of the Year								
Holiday	.	.	...		.690	1.058	.802	1.396
Non-holiday	.	.	...		.	.	.	.

<sup>a</sup>. The reference category is: Burns

<sup>b</sup>.  $X^2$ Chi-Sq. (Model 1) = 208.889; c. pseudo  $R^2$  (Nagelkerke) = 0.153 (15.3%); d.  $p = 0.000$

<sup>c</sup>.  $X^2$ Chi-Sq. (Model 2) = 325.575; f. pseudo  $R^2$  (Nagelkerke) = 0.230 (23.0%); g.  $p = 0.000$

Note. \* $p < .05$ ; Exp (B) = odds ratio; CI = confidence interval; LL = lower limit; UL = upper limit

In summary, the results of child pedestrian mortality versus burns, logistic regression Model 1 focused on the effect of socio-demographic variables of age, population group and sex on pedestrian mortality relative to burns. The 0 to 4 years old age group was found to be the only significant variable, whereas the middle and older age categories, population group and sex

were found to be not significant. The study found that children aged 0 to 4 years old are more vulnerable to dying from a burn as opposed to succumbing to pedestrian injuries.

However, in logistic regression Model 2, with respect to the influence of temporal factors on pedestrian deaths versus burns, both early morning to midday, and midday to early evening had a significant effect on child pedestrian mortality as opposed to burns, while the day of the week, weekend, holiday and non-holiday had no significant effect on child pedestrian mortality versus burns.

The findings relating to the logistic regression analyses of child pedestrian versus drowning mortality are discussed next.

## **7.2 Child Pedestrian versus Drowning Mortality**

In this analysis, logistic regression was used as an analytical technique for computing a dichotomous outcome. The logistic model enables analytical descriptions of the predictor (independent) variables that differentiate child pedestrian mortality from drowning mortality. A variety of logistic regressions were performed to assess the independent associations between each of the socio-demographic variables (refer Table 15 below, Model 1), and the temporal factors (refer Table 15 below, Model 2), including the risk for pedestrian mortality in relation to drowning mortality.

### *7.2.1 Logistic Regression Model 1: Analysis of socio-demographic variables*

The results derived from Model 1 indicate that, with the inclusion of the socio – demographic variables, sex, age and population groups, all these three variables were significant predictors of child pedestrian mortality relative to drowning. The study found that males ( $p < 0.003$ ) and



0 to 4 years old were more vulnerable [OR (95% CI): .655 (.494 – .869),  $p < 0.000$ ] than females in the same age group to a pedestrian mortality relative to drowning (refer Table 15 below, Model 1).

With respect to population group, the probability of coloured child [OR (95% CI): 4.997 (2.600 – 9.603),  $p < 0.000$ ] is five times, and a black child [OR (95% CI): 4.681 (1.933 – 11.333),  $p < 0.001$ ] four and a half times, and an Indian child three and half times [OR (95% CI): [3.778 (1.334 – 10.615),  $p < 0.012$ ]. when compared to a white child dying, from a pedestrian injury relative to drowning. Conversely, the likelihood of white children dying from pedestrian injuries as opposed to drowning was less when compared to all the other population groups (refer Table 15, Model 1).

Substantively, there was a significant difference for the independent variables of sex and population group in terms of child pedestrian mortality relative to drowning. When the socio-demographic variables of sex, age and population groups were included, indicatively Model 1 explained a 15.3% pseudo  $R^2$  (Nagelkerke) of the variance in the dependent variable. The overall logistic regression model was statistically significant (chi-square = 208.889,  $p = .000$ ) (see Table 15 below).

### *7.2.2 Logistic Regression Model 2: Analysis of temporal variables*

The effects for population groups were relatively similar to those from logistic regression Model 1. This in turn implies that, both a coloured [OR (95% CI): [5.01(2.60 – 9.65),  $p < 0.000$ ], and black child [OR (95% CI): [4.83(1.98 – 11.73),  $p < 0.001$ ] are five times, while an Indian child [OR (95% CI): 3.72(1.32 – 11.53), 0.013] is three and a half times more likely when compared to a white child, dying a pedestrian death as opposed to a drowning. In

addition, children from the coloured, black and Indian population groups are all vulnerable to a pedestrian mortality relative to drowning, irrespective of the time, day of the week or weekend, holiday and non-holiday. The overall logistic regression model was statistically significant (chi square = 325.575,  $p = .000$ ) (see Table 15 below).

**Table 15. Logistic regression analysis for child pedestrian deaths versus drowning mortality, Johannesburg (2001–2010)**

Independent Variable	Model 1				Model 2			
	Sig.	Odds Ratio	95% CI for Exp(B)		Sig.	Odds Ratio	95% CI for Exp(B)	
			LB	UB			LB	UB
Socio-Demographic Variable								
Sex								
Male	.003*	.655	.494	.869	.003*	.652	.491	.865
Female	0 <sup>b</sup>							
Age								
0–4 years	.000*	.327	.226	.473	.774	.942	.627	1.416
5–9 years	.811	.952	.635	1.427	.201	1.265	.882	1.816
10–14 years	0 <sup>b</sup>	.	.		.	.	.	.
Population Group								
Indian	.012*	3.778	1.344	10.615	.013*	3.729	1.320	10.539
Coloured	.000*	4.997	2.600	9.603	.000*	5.017	2.607	9.658
Black	.001*	4.681	1.933	11.333	.001*	4.831	1.989	11.735
White	0 <sup>b</sup>	.	.	0	.	.	.	.
Temporal Variables								
Time of Day								
05h00–12h59	.	.	...		.273	.791	.521	1.203
13h00–19h59	.	.	...		.119	.745	.515	1.079
20h00–23h59					.	.	.	.
00h00–4h59					.	.	.	.
Day of the Week								
Weekday	.	.	....		.923	.986	.748	1.301
Weekend	.	.	....		.	.	.	.
Time of the Year								
Holidays	.	.	...		.155	.826	.634	1.075
Non-holidays	.	.	...		.	.	.	.

<sup>a</sup>. The reference category is: Drowning

<sup>b</sup>.  $X^2$ Chi-Sq. (Model 1) – 208.889; c. pseudo  $R^2$  (Nagelkerke) – 0.153 (15.3%); d.  $p = 0.000$

<sup>c</sup>.  $X^2$ Chi-Sq. (Model 2) – 325.575; f. pseudo  $R^2$  (Nagelkerke) – 0.230 (23.5%); g.  $p = 0.000$ ; N=1442

Note. \* $p < .05$ ; Exp (B) = odds ratio; CI = confidence interval; LL = lower limit; UL = upper limit

In summary, for child pedestrian versus drowning mortality, the results from logistic regression Model 1 indicated that, with the inclusion of the socio – demographic variables of sex, age and population groups, males aged 0 to 4 years and population group were significant predictors for child pedestrian mortality relative to drowning mortality.

The analyses in logistic regression Model 2 revealed that, when including the temporal factors, children from the coloured, black and Indian population groups are all vulnerable to a pedestrian mortality as opposed to drowning, irrespective of the time, day of the week or weekend, holiday or non-holiday.

In summary, with regard to research objective 3, the logistic regression of child pedestrian mortality versus burns mortality, logistic regression model 1 investigated the variables of sex, age, and population group. The age group 0 to 4 years was the only significant variable while the middle and older age categories as well as sex and population group variables were not significant. Children aged 0 to 4 years are more vulnerable to dying from a burn as opposed to dying from pedestrian injuries. In addition, with respect to the effect of temporal variables on pedestrian mortality relative to burns, logistic regression Model 2 revealed that early morning to midday, and midday to early evening both had a significant effect, while the day of the week, weekend, holiday and non-holiday had no significant effect.

With respect to the logistic regression analyses of child pedestrian versus drowning mortality, the independent variables of sex, age and population group were found to have a significant effect. Logistic regression Model 1 showed that males aged 0 to 4 years old, and children from the coloured, black and Indian population groups are all vulnerable to a pedestrian death relative to drowning.

The results from logistic regression Model 2 were similar for the effect of the population variable on child pedestrian mortality versus drowning.

With respect to the influence of the temporal variables, the time, day of the week, or weekend, holiday and non-holiday were found to have no significant effect on child pedestrian mortality versus drowning. Thus, a child who is male, and associated with the population group, coloured, black and Indian, is vulnerable to a pedestrian death as opposed to drowning, irrespective of the time of the day, day of the week or weekend, holiday or non-holiday.

The discussion below focuses on objective four, and examines the neighbourhood-level predictors of childhood pedestrian mortality

## **8. NEIGHBOURHOOD-LEVEL PREDICTORS OF CHILDHOOD PEDESTRIAN MORTALITY**

Children's daily exposure to the hazards of the physical and social environment increases their vulnerability to a pedestrian mortality. This research objective focused on assessing the effect of neighbourhood-level predictors on childhood pedestrian mortality, by using negative binomial regression analyses. This analysis used several binomial regression models that were able to compute the number of pedestrian mortalities that had occurred when the children were exposed to the physical, and social environment, at the neighbourhood level.

A total of 413 child pedestrian deaths were registered for the City of Johannesburg for the period 2000 to 2010, of which 254 were male, and 154 were females, 140 were children aged 0 to 4 years, 176 children aged 5 to 9 years, and 95 children ages 10 to 14 years, while 373 of the children were black.

**Table 16. Child pedestrian deaths per neighbourhood in Johannesburg (2001–2010) (N= 413)**

	<b>Total</b>	<b>Mean</b>	<b>Standard</b>
<b>Deviation</b>			
All child pedestrian deaths	413	.81	2.963
Male child pedestrian deaths	254	.50	1.810
Female child pedestrian deaths	154	.30	1.225
Children 0–4 yrs. pedestrian deaths	140	.28	1.089
Children 5–9 yrs. pedestrian deaths	176	.35	1.378
Children 10–14 yrs. pedestrian deaths	95	.19	.729
Black children pedestrian deaths	373	.73	2.807

A negative binomial regression was computed to represent the standardised coefficients, and the standard errors, for the seven negative binomial regression models which described the total childhood pedestrian deaths for children from 0 to 14 years, the age groups 0 to 4 years, 5 to 9 years, 10 to 14 years, male and female children, and children classified as black in 508 Johannesburg neighbourhoods.

As indicated in the first column of Table 17 below, one of three neighbourhood factors, namely, concentrated disadvantage was significantly related with total pedestrian deaths, female pedestrian deaths, children in the age group 5 to 9 years, and children belonging to the black population group. In particular, concentrated disadvantage had a profound positive impact ( $\beta = .260, p < .01$ ), with a one unit change in concentrated disadvantage, leading to a 74% increase in the total number of childhood pedestrian deaths. In line with the method suggested by Kubrin (2010), the percentage change equals  $(100 \times [\exp (.260) - 1])$ . Similarly, female-headed households were also significantly influenced by concentrated disadvantage ( $\beta = .277, p < .05$ ),

with a one unit change in concentrated disadvantage, leading to a 72.3% increase in female pedestrian deaths.

Concentrated disadvantage also had a significant effect on children in the age group 0 to 5 years old ( $\beta = .278, p < .05$ ), with one unit change in concentrated disadvantage leading to a 72.2% increase in the pedestrian deaths in children aged 5 to 9 years old. Concentrated disadvantage also had a significantly negatively impact on black pedestrian deaths ( $\beta = -.256, p < .01$ ), with one unit change in concentrated disadvantage leading to a 25.6% increase or 74.4% decrease in black pedestrian deaths. Therefore, it would appear that concentrated disadvantage did not have a significant effect on male pedestrian deaths, including among boys from the 0 to 4 years old, and 10 to 14 years old age groups.

Less residential mobility (stability) also exerted a significant influence on pedestrians in the age group 0 to 4 years old ( $\beta = .269, p < .05$ ), with a one unit change in concentrated disadvantage leading to a 73.1% increase in deaths to pedestrians aged 0 to 4 years old. Instead, less residential mobility did not have any significant effect on the total pedestrian deaths, male pedestrian deaths, and pedestrian deaths among children in the age group 5 to 9 years old, and black pedestrian deaths.

Lastly, the neighbourhood characteristic of female-headed household had a significant impact on pedestrian deaths, particularly black pedestrian deaths ( $\beta = .331, p < .051$ ), with a one unit change in female-headed household leading to a 66.9% increase in black pedestrian deaths.

There was no significant effect of female-headed household on the total pedestrian deaths, male pedestrian deaths and the pedestrian deaths of children in the 0 to 4 years old, 5 to 9 years old and 10 to 14-year age group.

Overall, the results of the seven regression models for childhood pedestrian deaths revealed concentrated disadvantage to be significantly associated with total pedestrian deaths, female pedestrian deaths, and the pedestrian deaths of children aged 5 to 9 years old, but negatively associated for black pedestrians. Both less residential mobility (stability) and female-headed households had no significant effect on total pedestrian deaths, male and female pedestrian deaths, and pedestrian deaths of children in the 5 to 9 years old and 10 to 14 years old age groups. In addition, less residential mobility (stability) and female-headed households were positively associated with the pedestrian deaths of children aged 0 to 4 years old, and black pedestrian deaths respectively (see Table 17 below).

**Table 17. Negative binomial regression results for the impact of neighbourhood predictors on child pedestrian mortality, Johannesburg (2001–2010)**

Variable	Total Pedestrian Deaths	Male Pedestrian Deaths	Female Pedestrian Deaths	Child (0–4 yrs.) Pedestrian Deaths	Child (5–9 yrs.) Pedestrian Deaths	Child (10–14 yrs.) Pedestrian Deaths	Black Pedestrian Deaths
Concentrated disadvantage	<b>.260**</b> .0906	.173 .1006	<b>.277*</b> .1262	.133 .1271	<b>.278*</b> .1172	.147 .1344	<b>-.256**</b> .0980
Residential mobility (stability)	.033 .0903	-.022 .0997	.233 .1301	<b>.269*</b> .1327	.035 .1132	-.046 .1385	-.015 .0964
Female-headed household	-.049 .1187	-.033 .1362	-.123 .1744	-.141 .1829	-.005 .1545	-.190 .1966	<b>.331*</b> .1300
Intercept (constant)	-7.644***	-7.310***	-8.186***	-7826***	-7.407	-7.801	-6.784***
Likelihood ratio chi-square	8.900*	3.025	8.527*	5.567	6.007	1.993	12.618**

\*=  $p < 0.05$ , \*\*=  $p < 0.01$ , \*\*\* $p < 0.001$

To summarise, the results pertaining to research objective 4 showed that: (1) areas with higher concentrated disadvantage have higher rates of child pedestrian deaths; (2) areas with higher concentrated disadvantage have higher rates of female child pedestrian deaths; (3) rates of

pedestrian deaths among children 0 to 4 years old are higher in residentially stable areas, (i.e. in areas where there is less residential mobility); (4) areas with higher concentrated disadvantage have higher rates of pedestrian deaths among children aged 5 to 9 years old; (5) rates of black child pedestrian deaths are lower in areas with higher concentrated disadvantage; and, 6) rates of black child pedestrian deaths are higher in areas with higher concentrations of female-headed households.

## **9. INTEGRATED SUMMARY OF RESULTS**

The overarching focus of the study was to describe and examine the distribution, patterns, circumstances and neighbourhood characteristics of childhood pedestrian mortality from birth to 14 years in Johannesburg. The study was guided by the following four study objectives: (1) Overall incidence of selected child injury mortality; (2) Demographic and circumstantial risks: Childhood pedestrian versus motor vehicle passenger mortality; (3) Demographic and circumstantial risks: Childhood pedestrian versus burns and drowning mortality and (4) Neighbourhood-level predictors of childhood pedestrian mortality.

A comprehensive summary for the results relating to these four objectives reflected pedestrian mortality as the leading cause of death among children from birth to 14 years old in Johannesburg from 2001 to 2010. In general, pedestrian mortality was similar to burns and drowning mortality in terms of the socio – demographic variables of sex and population group, and temporal variables, but with some notable exceptions. Pedestrian mortality is more prevalent among all the age groups when compared to that of motor vehicle passengers, burns and drowning, except for burns and drowning mortality, where the 0 to 4 year olds were at higher risk compared to the other age groups.



Black males are more likely to be victims of pedestrian mortality, burns and drowning compared to white, Indian and coloured males. Pedestrian mortalities are more likely to occur from 16h00 to 19h59, over weekends, and during the school holidays. More importantly, when considering all the socio-demographic and temporal factors, children from birth to 14 years are more vulnerable to a pedestrian mortality as opposed to motor vehicle passenger, burns and drowning mortality.

However, when using logistic regression for child pedestrian versus motor vehicle passenger mortality, the findings showed that children from the coloured and black population groups are at high risk for pedestrian mortality irrespective of their sex and age. All children are equally vulnerable to a pedestrian mortality regardless of whether it is a weekday, or a weekend, holiday or non-holiday.

In addition, children are more vulnerable to a pedestrian mortality during the mornings and afternoons, as opposed to during the night. More importantly, irrespective of the child's sex and age, and temporal factors, children are more vulnerable to a pedestrian mortality as opposed to motor vehicle passengers.

For child pedestrian versus burn mortality, the age group 0 to 4 years old was the only significant variable, whereas for the middle and older age categories, including population group and sex, it was not significant. Children aged 0 to 4 years old are more vulnerable to dying from a burn as opposed to a pedestrian injury. With respect to the effect of temporal factors, early morning to midday, and midday to early evening had a significant effect, while the day of the week, weekend, holiday and non-holiday had no significant effect.

The logistic regression analyses of child pedestrian versus drowning mortality indicated that the socio – economic variables of sex and population group both had a significant effect. Males from the coloured, black and Indian population groups are all vulnerable to a pedestrian death relative to drowning.

With respect to the effect of temporal variables of the time of day, day of the week, or weekend, holiday and non-holiday had no significant effect. Thus, males from the coloured, black and Indian population groups are all vulnerable to a pedestrian death, irrespective of the time of the day, day of the week, or weekend, holiday or non-holiday as opposed to death by drowning.

Neighbourhood predictors such as concentrated disadvantage, residential mobility (stability), and female-headed households also had an effect on child pedestrian mortality. Areas with higher concentrated disadvantage have higher rates of child pedestrian deaths, particularly female child pedestrian mortalities. While the rate of pedestrian deaths among children aged 0 to 4 years old are higher in residentially stable areas (i.e. in areas where there is less residential mobility), the rate of pedestrian mortality among the 5 to 9 year olds are higher in areas with higher concentrated disadvantage. The rates of black child pedestrian deaths are lower in areas with higher concentrated disadvantage, and increased in areas with higher concentrations of female-headed households.

The following chapter presents a synthesis of the research results.

## **CHAPTER SIX**

### **DISCUSSION**

This chapter endeavours to synthesise the main research findings and to present a comprehensive narrative of the etiological and neighbourhood social determinants that were associated with fatal childhood pedestrian injuries among 0 to 14 year olds in the city Johannesburg for the period 2001 to 2010. The discussion will cover several main issues that correspond to the objectives in the study: (1) overall incidence of selected child injury pedestrian mortality (2) age concentration, (3) vulnerability of boys, (4) population groupings, (5) temporal influences (time of day, day of the week, month/season) and (6) neighbourhood predictors (i.e. concentrated disadvantage, residential mobility (stability), and female-headed households). This is followed by the conclusions to the study, recommendations for the prevention of child pedestrian deaths, limitations of the study, implications of the study for future research and the contributions of the study.

#### **1. OVERALL INCIDENCE OF SELECTED CHILD INJURY MORTALITY**

One of the many outcomes cited in this study indicated that children aged 0 to 14 years old are at greater risk of pedestrian mortality as compared to other causes of unintentional fatal injuries such as child motor vehicle passenger, burns and drowning mortality. The study confirmed that childhood pedestrian mortality was the leading cause of unintentional injury for children aged 0 to 14 years each year from 2001 to 2010 in the City of Johannesburg, South Africa. The average childhood pedestrian mortality rate of the 0 to 14-year age group (8.73 per 100 000 population) was twice that of motor vehicle passenger mortality (4.76 per 100 00 population) for the ten year period. When observing the trends in the mortality rates of these selected

unintentional injuries among children aged 0 to 14 years for each year throughout the ten-year period, pedestrian mortality distinctly reflected an increase. In addition, in certain years, the pedestrian mortality rate was twice the motor vehicle passenger, burns and drowning mortality rates. In general pedestrian mortality rates were noticeably higher in relation to motor vehicle passenger, burns and drowning mortality rates, except for the burns and drowning mortality rates among the 0 to 4 year age groups. There are also discrete differences for each year with these differences corresponding to the age group and type of unintentional injury mortality.

In the 0 to 14-year age group, traffic mortality for pedestrian and motor vehicle passengers ranked the highest, followed by the mortality rates for drowning and burns. Specifically, traffic pedestrian mortality in the 5 to 9-year age category displayed the highest rates, followed by the 0 to 4-year age category and then the 10 to 14-year age category. Children aged 5 to 9 years and 10 to 14 years consistently recorded higher rates for pedestrian deaths compared to motor vehicle passenger and other non-traffic deaths. Furthermore, in the 0 to 4-year-old age category deaths from burns were more prominent than pedestrian mortalities. These findings are in line with international studies on child pedestrian mortality. A recent WHO & UNICEF (2008) report indicated that for all age groups, except for the 15–19 year olds, road traffic mortality rates were greater in the LMICs than in the HICS. Surveys conducted in five Asian countries also concluded that road traffic injuries were the second leading cause of child injury mortality (Kumar & Ross, 2006; Rahman, 2005; Sitthi-Amorn, 2006) while a study from Africa conducted in Kampala, Uganda reported road pedestrian injuries as by far the most important cause of both morbidity and mortality for all ages. The study also found that school age children comprised the majority of victims (Hsia et al., 2011; Kumar, & Ross, 2006).

Nantulya and Reich (2003) and Evans and Brown (2003) highlighted the manifold disparities evident for road traffic injuries and mortality between the LICs and the MICs with respect to multiple risks to exposure, including socio-economic status, age, sex, place of residence, geographical location and education; morbidity and mortality; and the social outcomes of ill-health and access to treatment. These stark disparities provoke a paradigm shift in road safety and transport planning to ensure that the needs of all road users are taken into account. Evans and Brown (2003) reinforced the importance of paying particular attention to matters of social justice and equity with their call to policy makers to bear in mind that individual and structural policies do not affect all people or all pedestrians alike.

## **2. AGE CONCENTRATION**

The study revealed that, from 2001 to 2010, children in the 5 to 9 age category displayed the highest rate for pedestrian mortality compared to children in the 0 to 4 years and the 10 – 14-year age groups. Trends over this ten-year period indicated that in the 5 to 9-year age group, there were 11.02 deaths per 100 000 as compared to 8.09 deaths per 100 000 in the 0 to 4-year age group and 7.03 deaths per 100 000 population in the 10 to 14 years age group. In contrast to children as motor vehicle passengers in the 5 to 9 age group, there were 4.51 deaths per 100 000 as compared to 5.22 deaths per 100 000 in the 0 to 4-year age group and 4.59 deaths per 100 000 population in the 10 to 14 year age group, while for burns in the 5 to 9 year age group, there were 3.17 deaths per 100 000 as compared to 9.17 deaths per 100 000 in the 0 to 4 years age group and 5.13 deaths per 100 000 in the 10 to 14 years age group. With regards to drowning in the 5 to 9-year age group, there were 3.52 deaths per 100 000 population as compared to 8.51 deaths per 100 000 in the 0 to 4 years age group and 2.22 deaths per 100 population in the 10 to 14 years age group. Although pedestrian mortality in infants and toddlers (0–4 years) featured as a cause for concern in this ten-year study, this age group was

also susceptible to other unintentional mortality such as burns, drowning and as child motor vehicle passengers, and thus these would all require interventions tailored to ensure their prevention. This finding is supported by global studies on childhood pedestrian mortality. A possible reason for the over-representation of young children in pedestrian mortality may be as a consequence of their caregivers permitting these children to use roads when their perceptual motor and cognitive abilities are still insufficiently developed to enable them to navigate complex traffic environments (Assailly, 1997; Demetre, 1997).

A joint WHO and United Nations Children's Fund (UNICEF) (WHO, 2008) report indicated that injury is a leading cause of death and disability among children worldwide. Once children reach the age of five years, unintentional injuries constitute the biggest threat to their survival, with nearly all of these children being from approximately sixty LICs, including South Africa. Global studies on children have highlighted pedestrian injuries as the leading cause of death (e.g. Assailly, 1997; Australian Institute for Health & Welfare, 2005; Burrows, Van Niekerk, & LaFlamme, 2010, Christie, Cairns, & Towner, 2004; Hyder, Labinjo, & Muzaffar, 2006; Rivara, 1993; Toroyan & Peden, 2007; WHO, 2009). The vulnerability of children as pedestrians is also evident in African and, in particular, South African studies. In their report Peden and Hyder (2009) focused specifically on Africa's elevated rates of pedestrian mortality of 19.9 per 100 000 population. Hyder et al., (2009) also referred to systematic reviews that have been conducted on road traffic injuries of urban children and adolescents (<19 years), and these indicated projected incidence rates of over 100 per 100 000 population, including mean mortality rates of over 13 per 100 000 children, and a loss of healthy life of nearly 20 healthy life-years per 1000 children annually. The RTMC reported that, in South Africa, pedestrian fatal injuries were the leading cause of death among children younger than 15 years (RTMC, 2008). Furthermore, children between the ages of 5 and 9 years are at the greatest risk of

pedestrian death and injury, and comprise 49% of all child pedestrian mortality (RTMC, 2008). With respect to children aged 10 to 14 years, they are beginning to mature into preadolescents and young adolescents, and therefore they acquire more traffic experience as a result of which they gain confidence, become independent, begin to travel further from home, are more decisive, require less supervision and may also perhaps engage in risky pedestrian behaviour. Evidence indicates that it is because of this increased mobility that youth are often injured on relatively busy streets further from home (Agran et al., 1994).

When comparing childhood pedestrian mortality rates to children as motor vehicle passenger mortality rates for the ten-year period, the 5 to 9 year olds recorded the highest average rate (11.09 per 100 000 population) for pedestrians, and the lowest average rate for motor vehicle passengers (4.44 per 100 000 population), while the 10 to 14 year age group recorded a pedestrian rate of 7.03 per 100 000 population as opposed to a rate for children as motor vehicle passengers of 4.58 per 100 000 population. Infants and toddlers exhibited a high mortality rate as pedestrians (8.10 per 100 000 population), while the highest mortality rate for children as motor vehicle passengers (5.22 per 100 000 population) was among the 0 to 4-year age group. It was found that children across all age groups are more vulnerable as pedestrians rather than as motor vehicle passengers.

Further exploration into and a more thorough appreciation of the combination of unintentional injury risk factors are critical in developing preventative interventions aimed at those children who are at risk of unintentional injury and mortality (Beth, Lake, Eden, & Denney, 2004; Laflamme & Diderichsen, 2000; Morrongiello, 2005).

Global studies on road traffic injuries and mortality concur that children are more vulnerable to a pedestrian death particularly in the low to middle income countries where walking is the main means of mobility for children. Certain specific environmental factors also increase the risk for children using the road system, namely; sites with an increased traffic volume per day and poorly planned, designed and maintained road networks (Clifton, Burnier, & Akar, 2009; Pucher & Renne, 2003; Schieber & Vegega, 2002). Additional road traffic and environmental hazards include long, straight through roads that encourage high vehicle speeds as well as mixed land use comprising residential housing, schools and commercial outlets (Bly, Dix, & Stephenson, 1999; Clifton & Kreamer-Fults, 2007); a lack of pavements and facilities to separate road users, such as lanes for bicyclists and pavements for pedestrians (Kweon & Shin, 2005; Roberts et al., 1995); the existence of street vendor businesses; a lack of safe, efficient and affordable public transportation systems; inappropriate speeding, particularly in residential areas where children play or walk to and from school (Dunne, Asher, & Rivara, 1992; Durkin et al., 1999; Hippisley-Cox, Groom, Kendrick, Coupland, Webber, & Savelvich, 2002; Joly, Foggin, & Pless, 1991b; Roberts et al., 1995; Stevenson, 1997; Wazana, Kreuger, Raina, & Chambers, 1997).

This study found that, during the ten-year period, childhood pedestrian traffic mortality accounted for over 30% of all childhood unintentional injury deaths, averaging approximately 9/100,000 population. Burn rate mortality was not as high and averaged 5.17 per 100 000 population), while drowning rates averaged 5.07 per 100 000 population over the same period. When comparing child pedestrian mortality to burns and drowning in the 0 to 4-year age group, the average annual rates in this age group for burns and drowning recorded higher rates (9.15 per 100 000 population and 8.42 per 100 000 population) respectively relative to the pedestrian rates. In the 5 to 9-year age category, pedestrian mortality averaged 11.00 per 100 000



population per annum, while burns and drowning averaged 4.44 per 100 000 and 3.19 per 100 000 population respectively per annum. The 10 to 14-year age group recorded an average annual mortality rate of 7.08 per 100 000 population for pedestrians, while burns and drowning rates had annual averages of 1.90 per 100 000 population and 2.20 per 100 000 population respectively. The findings in this study are congruent with global studies on unintentional child injury mortality (WHO & UNICEF, 2008)

Pedestrians consistently, reported the highest unintentional injury mortality rates across all age categories, except for the 0 to 4-year age group where burns and drowning dominated. Previous studies have also found that burns and drowning mortality to be more pronounced among the 0 to 4 year olds, attributing this to their limited cognitive development, increasing curiosity and mobility, and also the constant need for supervision. These differences in exposure to risks are significant among the 0 to 4 year olds with respect to pedestrian injury mortality relative to burns and drowning, and concur with the findings from the logistic regression analyses. The probability of an infant and toddler dying from either burns or drowning is 75 % more likely compared to children from the age groups 5 to 9 years and 10 to 14 years relative to a pedestrian death. This observation concurs with the literature on unintentional mortality for burns and drowning among 0 to 4 year olds (Donson & Van Niekerk, 2012; Munro, Van Niekerk, & Seedat, et al., 2006; Saluja, Brenner, Morrongiello, Haynie, Rivera, & Cheng, 2004; Van Niekerk, Reimers, & Laflamme, 2007; Welandar et al., 2004; WHO & UNICEF, 2008).

Studies posit that children in the 5 to 9-year-old age group have been identified as the most vulnerable to road traffic injury mortality among the 0 to 14 year olds because of their developmental limitations, including diminutive size and limited cognitive abilities in navigating through the complex social, physical and contextual environs which surround them,

including their unpredictable behaviour. Unlike the 0 to 4 year olds, children in this age group are granted greater independence, and are therefore allowed to walk about freely to locations outside the home environment. This, in turn, increases their vulnerability to fatal pedestrian injuries (Rivara, 1995; WHO, 2013). African and South African studies also concur with this viewpoint (Nakitto, Howard, Lett, & Mutto, 2008; Sherriff, Mackenzie, Swart, Seedat, Bangdiwala, & Ngude, 2013; Sukhai, 2003; Swart, Laher, & Seedat, & Gantchev, 2014; Zwi, Forjuoh, Murugusampillay, Otero, & Watts, 1996). Global studies support the view that pedestrian mortality is the most prevalent among the 5 to 9 year olds (Ampofo-Boateng & Thompson, 1991; Bergman, Gray, Moffat, Simpson, & Rivara, 2002; Posner, Liao, Winston, Cnaan, Shaw, & Durbin, 2002; Stevenson, 1997; Turner et al., 2004; WHO, 2013; Zeedyk, Wallace, & Spry, 2002).

Pedestrian mortality among children 0 to 4 years reflected a significant outcome in neighbourhoods in which there was residential stability and a lesser migration of families compared to other neighbourhoods. These findings are consistent with previous studies which focused on the developmental vulnerability of this age group to pedestrian injuries and mortality. It is plausible to suggest that, when families have lived in a neighbourhood for many years, the caregivers become familiar with their environments and, thus, they may become complacent about safe spaces and supervision within their immediate home environment, therefore allowing their children to be exposed to often precarious situations. Residential stability or less people moving out of neighbourhoods do not necessarily imply that the environment is safe for children. Many families in low-income settings are not able to afford to relocate to safer physical and social environments. Although neighbourhoods may be stable, many communities, particularly in low-income settings, live in adverse contextual conditions which are often associated with a social gradient typified by concentrations of endemic poverty

such as a lack of safe recreational spaces, absence of fencing around the houses, low-cost housing, family size, minimal educational achievement, socially and culturally determined attitudes and practices such as those relating to supervision, independence and appropriate play activities for children, family disruption (single and/or divorced parents), violence and crime, and the absence or lack of community cohesion and social assets. These, in turn, often manifest as increased levels of childhood pedestrian and other unintentional deaths (Agran, Winn, Anderson, & Del Valle, 1998; Borowy, 2013; Laflamme & Engstrom, 2002; LaFlamme, Burrows, & Hasselberg, 2009; Morrongellio et al., 2007; Reading, et al., 2005; Rivara, 1995; Roberts, 2011; Towner et al., 2005).

### **3. THE VULNERABILITY OF BOYS**

The majority of studies on road traffic injuries and mortality provide evidence of a strong relationship between sex, road safety behaviour and road traffic injury and mortality. In most regions worldwide, at least twice as many boys are killed or injured in road traffic crashes compared to the number of girls. It is possible that this disproportion may be attributed to the risk exposure emanating from two factors, namely, socialisation and behavioural differences. It would appear that, compared to girls, caregivers permit boys more time outdoors unaccompanied by adults with their attitudes and practices connected to male independence serving to justify such actions (Assaily, 1997; Safe Kids, 2006; WHO, 2008). This study recorded that, in the 0 to 14-year age group, males were more vulnerable to pedestrian mortality than females, with a similar trend noticeable across the specific age groups. In children from birth to 14 years, males exhibited a 67% higher pedestrian mortality rate compared to females (10.79 deaths per 100,000 for males compared to 6.45 deaths per 100, 000 for females). Among the children ages 0 to 4 years, the rate of pedestrian mortality for males was 1.56 times the rate for females; for children aged 5 to 9 years, the male rate was 1.80 times the female rate and,

for the 10 to 14 year olds, the male rate was 1.66 times the female rate. This study concurs with other studies that reflected male childhood pedestrian death rates to be much higher than the rates for females. These findings may, in turn, be attributed to male pedestrians enjoying greater independence and mobility than girls in relation to freedom of movement (Clifton & Kremer-Fults, 2007; Johnson et al., 2004; Laflamme & Diderichsen, 2000; Schieber & Vegega, 2002; WHO, 2008). One may also speculate that, compared to girls, boys are often considered to be more 'impulsive' and perhaps more easily distracted, darting out into streets in traffic situations (Assaily, 1997). Morrongiello and Lasenby-Lessard (2007) posit that the socialisation practices of parents/caregivers indicate that both mothers and fathers both responded in a similar way, but differently to the risk taking behaviours of their sons and daughters. It would appear that sons received overt encouragement for risk taking whereas daughters were advised both against risk taking and about their vulnerability to injury. Mothers were also more inclined than fathers to interpret behaviours that could lead to injury in terms of safety for their daughters but in terms of discipline for their sons. However, the socialisation and interpretation of sex and intuition in relation to road-user behaviour requires further empirical scrutiny.

When comparing pedestrian mortality in relation to drowning, the findings were significant with regard to sex. Males were at higher risk for pedestrian mortality as opposed to a drowning mortality. This finding was consistent with numerous studies conducted on these categories of childhood unintentional mortality and which were alluded to in previous discussions (Donson & Van Niekerk, 2012).

#### **4. POPULATION GROUPING**

Childhood pedestrian injuries and mortality in South Africa are clearly underscored by geopolitical ('race' and class) dimensions, social determinants and poverty. The study found that children of colour, predominantly black children, who reside in urban slums in poverty stricken conditions exhibited the highest annual pedestrian mortality rate of 10.22 deaths per 100,000 population, nearly twice the rate of the next highest population group of coloured children with a rate of 5.19 deaths per 100 000 population over the ten-year period of analysis. White children at 1.64 deaths per 100 000 population, and Indian children with 3.68 deaths per 100 000 population displayed significantly lower rates of childhood pedestrian deaths compared to black and coloured children. An exponential growth in urbanisation, including the proliferation of 'informal settlements', play a role in the existing inequalities in respect of fatal child pedestrian injuries among South Africa's various population groups. These findings are also alluded to in studies that agree on the detrimental effects of inequality, inequity and poverty on child pedestrian safety (Butchart, Kruger, & Lekoba, 2000; Clifton & Kreamer-Kults, 2007; Cohen, 2006; Dougherty, Pless, & Wilkins, 1990; Graham, Glaister, & Anderson, 2005; Towner et al., 2005; Jones, Lyons, John, & Palmer, 2005; Laflamme & Diderichsen, 2000; Rivara & Barber, 1985; South African Cities Network, 2011; Van Niekerk, Seedat, Bulbulia, & Kruger, 2001).

This study also indicated that children from the different population groups who live in a low income context are at higher risk of pedestrian injuries and mortality as opposed to those living in more affluent circumstances (Borowy, 2013; Mock, Quansah, Krishnan, Arreola-Risa, & Rivara, 2004). Black children recorded the highest fatal pedestrian injury rates followed by coloured, Indian and, lastly, white children. Conversely, death rates were the highest among white children followed by Indian, coloured and then black children. children as motor vehicle

passengers. The regression analysis indicated that population group had a pronounced effect on child pedestrian mortality when both demographic and temporal variables were incorporated in the two models. A coloured child was six times more likely than an Indian or black child as opposed to a white child of pedestrian mortality relative to a motor vehicle passenger fatality, while Indian and black children are three times more likely than a white child to be vulnerable to a fatal pedestrian injury compared to a motor vehicle passenger fatality. Infants and young children are also vulnerable to fatal pedestrian injuries compared to motor vehicle passenger fatalities. In other words, irrespective of age, a child is more vulnerable to a fatal pedestrian injury compared to a motor vehicle passenger fatality. The above findings may be attributed to the strong association between socio-economic status (SES) and vehicle ownership rates and which is, in turn, directly linked to the prevalence of walking in low SES households. A recent report produced by the Human Sciences Research Council (2014) highlighted that poverty remains a racial issue in South Africa. The report further alluded to increased levels of poverty particularly among the black and coloured population groups although not among the Indian and white population groups. The majority of the black and coloured population groups are still marginalised and poor and are not able to afford to own a motor vehicle.

Although cars have benefits for children, poor children are more likely to be killed or injured in road crashes compared to those from affluent homes. For example, it has been shown that the lack of access to a car increases pedestrian injury risk twofold (Johnson et al., 2004; Mohan et al., 2006). The findings attest to the findings of studies alluded to earlier. Mohan et al. (2006) posited that the increasing growth in vehicle ownership has contributed to an escalation in global road accident injuries. Without proper planning, this growth in motorisation may increase the exposure to risk and endanger the lives of both pedestrians and cyclists as well as reducing the mobility of pedestrians and cyclists. Nevertheless, despite the rapid growth in

motorised traffic, the majority of families in low income and middle income countries are unlikely to own a car within the next 25 years. However, it is these families who also have to bear the costs of roads, climate change as well as a high proportion of the road traffic injuries and mortality (Roberts, 2011). This, in turn, emphasises the importance of ensuring that appropriate road safety measures and planning address the increase in motorisation as well as prioritising the needs of road users.

Overall, the research results showed that, on average, black children exhibit higher mortality rates for pedestrian (10.16 per 100 000 population) and burns (5.42 per 100 000 population) mortality, although not for drowning (5.32 per 100 000 population) when compared to children from the other population groups in these unintentional injury deaths over the ten-year period. Pedestrian mortality rates remain the highest for black children at 10.16 per 100 000 population, followed by coloured children at 5.25 per 100 000 population, Indian children at 3.36 per 100 000 population and, lastly, white children at 1.64 per 100 000 population. These results concur with the findings of previous studies conducted in South Africa on unintentional injury mortality (Donson & Van Niekerk, 2012; Sukhai, 2003; Swart et al., 2014; Van Niekerk et al., 2007).

When comparing pedestrian mortality versus burns mortality, the findings were significant for the demographic variable of population group. Indian, Coloured and black children are all equally likely to die from a pedestrian death, and two and half times more likely than white children to die from a pedestrian death as compared to a burn death. With respect to pedestrian mortality versus drowning, the findings were once again significant in respect of population group. Coloured and black children are approximately five times more likely than Indian children as opposed to white children to die of a pedestrian death as opposed to drowning,

while Indian children are three times more likely than white children to be at risk of a pedestrian mortality as opposed to drowning. These varying vulnerabilities among the different population groups attest to the huge contrasting economic divide between the affluent and the disadvantaged or the 'haves' and 'have not's' in South Africa. Laflamme and Diderichsen (2000) mention that injury risk and mortality increase with socio-economic deprivation. It is, thus, essential that child pedestrian policy and safety promotion focus on disadvantaged communities. As reflected in the findings of this study international, African and national studies all indicate that children living in disadvantaged and under-resourced areas are more susceptible to unintentional injuries and mortality being pedestrians, and for burns and drowning (Butchart et al., 2000; Laflamme et al., 2009; Rivara, 1990; WHO & UNICEF, 2008).

An additional finding which was significant was that the rate of black child pedestrian deaths was lower in areas with higher concentrated disadvantage. We may postulate that the outcome should be higher for black children living in areas of endemic poverty. However, the converse also makes sense in that, in neighbourhoods with concentrated disadvantage, it is presumed that fewer people own cars and, thus, there is less vehicular traffic than would otherwise be expected. Informal settlements are high density neighbourhoods with single and narrow streets which could also preclude the high incidences of fatal pedestrian injuries. Further research on these issues may provide more insight, and also complement the existing evidence base, particularly in South Africa.

Further outcomes from the analysis alluded to the fact that the rates of black child pedestrian deaths were higher in areas with a higher concentration of female-headed households. Laflamme and Diderichsen (2000) mentioned that a study conducted in Memphis (US) had reported twice the rate of pedestrian injuries for blacks, lower household incomes, more



children living in female-headed households, more families living below the poverty line, and greater household crowding. South Africa is characterised by a gender disparity in income with female-headed households tending to be poorer than those headed by males (Human Sciences Research Council, 2014). A study conducted in South Africa documented that the poverty rate among female-headed households is 60%. The study highlighted that this exacerbated the responsibility and burden on women, which instead has an impact on the rate of hospitalised unintentional injuries in children, and therefore compromising the safety of children (Van Niekerk et al., 2007).

Roberts et al. (1996) posited that sole parenthood was a significant injury risk factor for pedestrian injury in the Auckland region of New Zealand, while Munro et al. (2005) reported that some mothers deflected the responsibility of preventing unintentional injuries to children solely on the environment. Young mothers often expect too much from their young children, possibly because they are either not aware, or they are not informed about the developmental milestones and behaviours associated with increasing age. It is understandable that complete supervision is unrealistic, and therefore ensuring a safe home environment is necessary to prevent injury risks and mortality. However, in economically deprived households, the affordability of safety equipment often precludes the promotion of safety within the home and immediate environment, e.g. smoke alarms, stairway gates, gates and fences around the house, etc. (Kendrick et al., 2005, Ueland & Kraft, 2005).

The ‘absence’ of the other partner may exacerbate the already stressful role of a single parent who has the dual responsibility of parenting, while the stress of unemployment may also be an added challenge. In view of the high cost or limited availability preventing many children from enrolling in after school programmes or childcare, these children may be more likely play on

public streets and pavements, thereby increasing their exposure to traffic, and resulting in higher rates of pedestrian injury. When combined with the physical environment, and the lack of supervision, these challenges may also constitute potential factors that contribute to the high rates of pedestrian injury in low income neighbourhoods (Dougherty et al., 1990; Durkin et al., 2004; Runyan, 2003).

## **5. TEMPORAL INFLUENCES**

The study also examined how temporal factors contributed to fatal child pedestrian injuries. The study found that children are more vulnerable to pedestrian deaths during the day as opposed to the night. In addition, children from all the age categories displayed a higher percentage of pedestrian mortality during the late afternoon until early evening (16h00–19h59), followed by the afternoon (12h00–15h59) and then morning (0h00–11h59). In other words, the highest childhood mortality across all ages was recorded during 16h00 to 19h59. A higher percentage of deaths for children across all age categories was recorded over weekends (Saturday and Sunday). It is worth noting that children from all the age groups were prone to fatal pedestrian injuries throughout the year, although the months of December, September, August and January reflected a slightly higher percentages of fatal injuries compared to the other months. These findings are not surprising in low income countries where the main mode of mobility in children is walking. Walking to and from school, rather than being transported in cars is generally both costly and unaffordable for most families. Similarly playing in the streets is commonplace for children, where there is a lack of safe recreational and public spaces (Clifton et al., 2007; Laflamme & Diderichsen, 2000). The findings of global, African and urban South African studies conducted for this age spectrum are in line with the findings of this study (Hsia et al., 2011; Sheriff, Makenzie, Swart, Seedat, Bangdiwala, & Ngude, 2013; Sheriff et al., 2013; Sukhai, 2003; WHO, 2009).

When comparing fatal pedestrian injuries and children as motor vehicle passengers, the percentage of deaths recorded is higher for pedestrians during the late afternoon to early evening (16h00–19h59), mid-afternoon to early afternoon (12h00–15h59) and, to a lesser extent, from early morning until midday (08h00–11h59). The study showed that temporal predictors had a significant influence on child pedestrian mortality. Children were almost twice to three times more vulnerable as pedestrians from 16h00 to 19h59 and 12h00 to 15h59 than at night compared to their susceptibility as motor vehicle passengers.

Literature alludes to additional underlying key risk factors which may contribute to such fatal pedestrian injuries, including the time at which school ends, the proximity of the school to the home, the child dashing out into the street between parked cars, or the child wandering off not far from his/her home in a residential area. These findings are in line with evidence from previous studies which showed that, during these times reflected in the findings above, children are either walking to and from school, or playing in the streets, and are therefore more likely to be killed or injured alternate to other times.

Other factors which predispose children's vulnerability as pedestrians has been documented in previous studies, for example, lack of supervision, lack of safe recreational spaces and inability to afford after school care etc. (Dissanayake, Aryaija & Priyantha Wedagama, 2009; Nakitto et al., 2008; Munro et al., 2006; Wazana et al., 1997). Other important and related factors that should also be taken into account include parental and caregiver expectations and lack of supervision, level of parental education, employment status, road design, housing density, overcrowding and family stress. Studies have posited that income status, younger age of children and traffic volumes appear to be significantly related to childhood pedestrian injury but without underscoring the effects of speed, driver behaviour and alcohol and drug use

(Dunne, Asher, & Rivara, 1992; Durkin et al., 1999; Hippisley-Cox, Groom, Kendrick, Coupland, Webber, & Savelvich, 2002; Wazana et al., 1997).

The study found that temporal factors were a significant predictor variable for childhood pedestrian mortality versus motor vehicle passengers. Weekends were significant for childhood pedestrian mortality relative to children as motor vehicle passengers. However, children were more vulnerable to pedestrian mortality as opposed to motor vehicle passenger mortality both on weekdays and over weekends. These are times during the day when children are walking to and from school, doing errands, and also playing on streets, particularly in low income settings where there is a lack of safe recreational spaces.

With respect to the month of the year, child pedestrian mortality among all the age groups was higher for the months of December, November, September, August and January and lower for the months of February, May and July. In general, higher pedestrian deaths were recorded for all age groups during the school holidays, namely, December, January, April, July and September, although children were also vulnerable during the other months of the year, albeit to a lesser extent.

The months of December and January are school holidays and also festive months. Thus, during these months, the streets are occupied by children, and there is also an increase in vehicular traffic with tourists and families going on holiday. This may in turn compromise the safety of children, and thus increased vigilance is required to prevent fatal pedestrian injuries. African and South African studies have shown that, in general, there is an increase in fatal child pedestrian injuries over weekends, as well as during school holidays and festive periods (Hsia

et al., 2011; Swart et al., 2014; Sukhai et al., 2009; WHO African Region, 2009; Mock et al., 2004, Solagberu et al., 2014).

These findings serve as a warning to policy makers and traffic enforcement officers that, although children as road users are more susceptible during the months of December, January, April, July, and September, they are also vulnerable, although to a lesser extent, during the other months of the year. Traffic enforcement should consider implementing prevention initiatives throughout the year to prevent child pedestrian injury and mortality.

Temporal factors were also significant for the time of day in terms of pedestrian mortality relative to burns mortality. The findings revealed that children are more vulnerable to a pedestrian death as opposed to burns in the morning from 05h00 to 12h59, and in the afternoon from 13h00 to 19h59, rather than at night.

Infants and toddlers are also 67% more vulnerable to death by drowning, then children aged 5 to 9 years, and 10 to 14 years, as opposed to pedestrian deaths, irrespective of the time of day, day of the week, and whether it is either holidays or not. The findings concur with previous studies on fatal unintentional injuries in infants and children. It is plausible to suggest that these fatal injuries may occur without warning within, or in the proximity of the home environment. This may, in turn be attributed to the caregiver leaving the child unsupervised for a short time near water, and or in a bath tub, while being distracted by other activities.

Pedestrian injury or mortality may, perhaps, be minimised with respect to infants and toddlers as they are usually attended to by their caregivers in road traffic environments. Studies reflect that the lack of caregiver supervision and also complacency may predispose children to risk

situations. However, without detracting from this important responsibility, it is also necessary to bear in mind that caregivers have multiple roles and responsibilities with which to contend to keep the family structure functioning, and that these challenging roles of caregivers need to be contextualised with regards to active supervision and child safety (Morengiello et al., 2005; Morengillio et al., 2009; Van Niekerk et al., 2007; Ueland & Kraft, 1994).

Although the primary focus of this study was on children in relation to the traffic environment, the study also showed the extent to which children are affected by fatal non - traffic injuries such as burns and drowning. The findings discussed above on socio- demographic factors such as age, sex (vulnerability of boys), disadvantaged population groups (blacks and coloured) and temporal factors which include time of day, day of the week and weekends, and holiday and non-holiday months complement studies which emphasise the combined role of education, passive engineering, enforcement of road traffic laws and supervision as critical and significant intervention mediators for the prevention of fatal childhood injuries (AIHW, 2005; Duperrex, Roberts & Bunn, 2002; Laflamme & Diderichsen, 2000; Morrongiello et al., 2009).

## **6. NEIGHBOURHOOD PREDICTORS**

When assessing the effects of neighbourhood predictors, the study findings indicated that concentrated disadvantage (which is associated with low educational attainment, low household income, unemployment, informal dwellings, low educational attendance, high household density, and black residents), residential stability (i.e. less residential mobility) and female-headed households were all significantly associated with fatal child pedestrian injuries in Johannesburg. The variable concentrated disadvantage was positively associated with the total number of pedestrian deaths in children aged 0 to 14 years old. There was also evidence that children aged between 0 and 14 year olds encounter a multiplicity of challenges that are

underpinned by social, developmental and environmental determinants, such as poverty, mobility, independence, crossing busy intersections, impulsive crossing of roads, and assessing the speed and distance of a vehicle, lack of supervision, as well as increased urbanisation and motorisation, all of which increase their susceptibility to pedestrian injuries and mortality (Agran, Winn & Anderson, 1998; Barton & Schwebel, 2007; Butchart et al., 2000; Cohen, 2006; Dandona et al., 2008; Dougherty et al., 1990; Hewson, 2005; Lawrence, 2012; Morrongiello et al., 2009; Peden et al., 2008; Roberts & Coggan, 1994; Schieber & Vegega, 2002; South African Cities Network, 2011).

A WHO (2800) report cited a strong association between socioeconomic status and the incidence of child road traffic injury. Laflamme and Diderichsen (2000) posit that, in the industrialised world, traffic mortality, in addition to being the most common cause of fatal injury among children, adolescents and young adults, is also acknowledged as one of the acute causes of mortality with the steepest social class gradient. Poverty has a profound impact on all types of injuries, with the majority of poor living in low income countries. There is no doubt that injury risks increase with socioeconomic deprivation. This is particularly evident in high income countries where the risk for children and young adults are higher if they come from families of a lower social class.

Laflamme and Diderichsen (2000) further stated that the annual injury rate of both fatal and non-fatal injuries of children (0–14 years) living in the poorest income quintile neighbourhoods of Montreal in Canada was four times of children living in the less poor neighbourhoods. The proportion of pedestrian injuries suffered by deprived children is between three to four times more than children from more affluent families (Roberts & Coggan, 1994). There is evidence of a strong connection between poverty and childhood pedestrian injuries in several studies

documented in numerous countries. Socioeconomic inequalities are certainly one of the main contributors to childhood pedestrian mortality (Roberts & Coggan, 1994; Rivara, 1990). In some of the LICs, family size and family income determine the choice of transport used, and may also be associated with risk of the pedestrian injury to children. The bulk of the childhood injury burden is to be found in the low and middle income countries, and, in these countries, poor children are disproportionately affected (Berger, & Mohan, 1996; Clifton et al., 2007; Laflamme et al., 2009; Towner et al., 2005).

In their investigation of 20 years of research on socioeconomic inequalities and children's unintentional injuries, Laflamme et al., (2010), document that childhood injuries are inextricably linked to social inequalities, and recommend that the prevention of inequities in child safety address the causality of injuries and poverty. They further mention that, in view of the fact that injuries are preventable, differences in socioeconomic status does not necessarily have to play a role in with respect to safety. At present, the burden of injury rests with the poor, and this burden will continue to escalate unless the economic disparities underpinning injuries in low income settings are not tackled expeditiously. Safety should not necessarily be the preserve of the wealthy but, instead, it should be made accessible to all.

Although there has not been in depth research into the relationship between SES and vehicle ownership rates, there is however, strong evidence of such a link, as well as a direct link with the prevalence of walking trips and not owning a vehicle in low SES households. Although access to cars does have benefits for children since they do not have to walk, and may feel protected from busy traffic, poor children who have less access to cars compared to the children from more affluent homes, are more likely to be killed or injured as pedestrians in road crashes



compared to those from affluent homes. The lack of access to a car increases the risk of pedestrian injury two fold (Collins & Kearns, 2005; Johnson, Rai, Geyer & Ragland, 2004).

A recent study of neighbourhood effects on overall childhood injury rates revealed that the seriousness of the injury requiring emergency medical attention, may be attributed to both family living characteristics (living in rented accommodation, teenage mothers) and community factors (living in severely deprived neighbourhoods with high levels of violent crime, homes without smoke alarms, stair gates or the safe storage of sharp objects). Overall, the results of the study highlighted the importance of the neighbourhood context, specifically in relation to child pedestrian mortality (Kendrick et al., 2005); Noland, Klein & Tulach, 2013).

The social disorganisation theory, which is embedded in criminology, also alludes to the influence of neighbourhood effects, particularly on crime and violence and injuries, (Swart, 2014). Kendrick et al., (2005) concluded that reducing the inequalities in injury rates may be achieved by focusing prevention efforts on families rather than on neighbourhoods. However, in practice, interventions at both levels are likely to be necessary.

The study findings showed that areas with higher concentrated disadvantage have higher rates of pedestrian deaths among the 0-14 year olds, but especially among children aged between 5 and 9 years old. This result is congruent with global studies on childhood pedestrian deaths in this age category (Johnson et al., 2004). Laflamme et al., (2010) cited numerous studies in Europe, including Greece and the United Kingdom, in which children in this age group are identified as being the most vulnerable to road traffic injuries at both the individual and area levels because of concentrated socioeconomic deprivation (Rivara, 1995; WHO, 2013).

African and South African studies concur with these findings (Nakitto, et al., 2008; Sherriff et al., 2013).

The rate of pedestrian deaths among children aged 0 to 4 years was significantly related to areas in which there is residential stability, (i.e. less residential mobility). This is consistent with previous studies which linked the developmental vulnerability of this age group to pedestrian injuries. In unstable environments, caregivers may not be able to cope with the demands and stresses associated with unemployment, together with family structure and their roles and responsibilities. They may become distracted and complacent about safe spaces and supervision within their immediate home environment, and this could result in children being exposed to the likelihood of precarious situations (Van Niekerk et al., 2007; Ueland & Kraft, 1996). The socioeconomic position of the individual and/or family influences, for example, the degree of parental supervision (Laflamme & Diderichsen, 2000).

In addition, the socioeconomic status of a family/caregiver, is linked to the affordability of, and access to day care centres, or the hiring of a caregiver on a daily basis to supervise the child's daily activities. Studies have also highlighted that areas with adverse contextual conditions are often associated with a social gradient which is typified by concentrations of endemic poverty. These factors, which are linked to concentrated disadvantage, may also be encapsulated within the broader social environment in communities/neighbourhoods as reflected and associated with the implementation of the systems approach.

The familial/relational aspect may be linked to minimal educational achievement as well as socially and culturally-determined attitudes and practices, for example, those relating to supervision, independence and appropriate play activities for children, as well as family

disruption (single and/or divorced parents and family size). Both the community and the built environment are associated with the physical environment which may be characterised by low cost housing, a lack of safe recreational spaces, the absence of fencing around the houses and violence and crime, while the social environment may be characterised by the absence or lack of community cohesion and social assets/capital.

However, both at the individual and neighbourhood level, it is possible for either of these factors to be modified to promote community connectedness and well-being, so that neighbourhoods become safe spaces for pedestrian mobility and recreation. Alternatively, these factors are allowed to continue and manifest as increased levels of childhood pedestrian and other unintentional deaths (Johnson et al., 2004; Keandrick et al., 2005; Laflamme et al., 2010; Putnam, 1993; Reading et al., 2005; Sampson et al., 1997, Towner et al., 2005).

The sociology of childhood pedestrian injuries is increasingly receiving renewed attention. Schieber and Vegega (2002) posit a social paradigm that contextualises pedestrian injuries as an interaction between social factors in the environment that focus on family and socio-economic status (SES), place of residence, and type of housing, poverty, highest parental education achieved, supervision of children, degree of dependence on walking for the purposes of transportation, availability of recreational space, and the design and maintenance of the roads. These factors are all likely to impact on children's vulnerability to injury and mortality (Srinivasan, O' Fallon & Dearry, 2003; Tandy, 1999).

Researchers have demonstrated a relationship between child behaviour characteristics and injury rates, while other studies have examined family characteristics such as the relationships between parental/family stress, parental beliefs and emotions, single parenthood, low maternal

education, low maternal age at birth, poor housing, large family size, parental drug and alcohol abuse, parental attitudes and preventative behaviour and the presence or absence of social supports and childhood injury (Beth, Lake, Eden, & Denney, 2004; Assailly, 1997). It may be that further exploration into the interactions of this multiplicity of social factors should be considered in order to help improve our understanding of the relationship between children, caregivers, parents and the physical and the social environment on the rates of childhood injury. (Beth et al., 2004; Laflamme & Diderichsen, 2000).

Within the ambit of the systems approach to road and transportation safety, previous studies have already alluded to the impact of both the social and the physical environs on childhood pedestrian injuries and deaths. However, there have been limited studies which have examined the role of the social environment in walking and driving behaviour (Johnson et al., 2004; Leyden, 2003; Srinivasan et al., 2003). Recently, the terms social capital, which Putnam (1993) broadly characterizes as referring to those features of social organisation such as networks, norms of reciprocity, and trust in others to facilitate cooperation between citizens for mutual benefit, and collective efficacy which alludes to the social cohesion of the neighbourhood and its residents as their willingness to intervene for the common good, have been encapsulated within the context of the social environment (Sampson, Raudenbush, & Earls, 1997).

Runyan (2003) suggested that social norms, cues and pressures may explain the higher pedestrian injury rates in low income neighbourhoods. These norms may include different expectations of behaviour or different requirements for safety either from individual households and or the values of neighbours. It may thus be acceptable in some neighbourhoods for children to play in the street, or encouraged by their parents to walk to school, or to play outside when it is dark. However, in some areas, parents may not allow such behaviour. In

many if not most of the communities in South Africa, there is an absence of safe pedestrian environments. Neighbourhoods which are designed to encourage walking may help to generate social capital among the residents (Kim & Kaplan, 2004; Leyden, 2003; Lund, 2002). Several authors posit that the stability of a neighbourhood impacts on the ability of its residents to develop social capital, collective efficacy and a sense of community (Davidson, Cotter, McMillan, & Chavis, 1986; Putnam, 1993; Sampson et al., 1997). The fostering of these social assets may help to prevent childhood pedestrian injury.

Residential stability (less residential mobility) is another key neighbourhood feature that also exhibited a positively significant association with children in the age group 0 to 4 years. Evidence from global studies continues to indicate that childhood pedestrian deaths are more prevalent in LICs, as well as increasing residential mobility, or demographic shifts of poorer families and their children who reside in disadvantaged areas within these HICs (Hippisley-Cox et al., 2002). Some researchers maintain that much of the evidence on social inequalities in injury risk comes from ecological studies which compare the injury rates between rich and poor areas, rather than between rich and poor families from different countries (Joly, Foggin, & Pless, 1991b; Faelker, Pickett, & Brison, 2000; Hippisley-Cox et al., 2002).

In addition, motorisation and urbanisation are burgeoning rapidly in much of the world today, while the safe mobility, particularly of children, is rarely taken into account (Borowy, 2013; Roberts, 2011). Certain specific environmental factors increase the risk for children using the road system, namely; sites with a volume of traffic exceeding 15 000 motor vehicles per day; poor planning of land use and road networks, including long, straight, through roads that encourage high vehicle speeds, together with mixed land use comprising residential housing, schools and commercial outlets (Bly, Dix, & Stephenson, 1999; Kweon & Shin, (2005);

Frumkin, 2003; Petch & Henson, 2000), a lack of playgrounds, resulting in children playing in the road; a lack of facilities to separate road users such as lanes for bicyclists and pavements for pedestrians (Kweon & Shin, 2005; Roberts et al., 1995); the existence of street vendor businesses for which children may work; a lack of safe, efficient public transportation systems; inappropriate speeds, particularly in residential areas where children play or walk to and from school (Joly et al., 1991a; Kweon & Shin, 2005; Berger & Mohan, 1996; Stevenson, 1997).

Some studies also posit that income status, younger aged children and traffic volume appear to significantly relate to childhood pedestrian injury, and also highlighting the effects of speed, driver behaviour and alcohol and drug use (Durkin, Araque, Lubman, & Barlow, 1999; Dunne, Asher, & Rivara., 1992; Hippisley-Cox et al., 2002; Wazana et al., 1997).

Neighbourhoods with a higher concentrated disadvantage displayed a significant positive association with female pedestrian deaths. South Africa is characterised by pronounced socioeconomic inequalities and residential segregation as a result of the apartheid legacy. This is particularly evident in the case of many South African families who live in conditions of deprivation and adversity. Evidence shows that the majority (60.5%) of South African children and adolescents (aged less than 18 years) live in poverty, while over a third (35.6%) live in households where there are no employed adults (Jamie et al., 2011).

Interestingly, the evidence concerning socioeconomic differences in relation to sex is conflicting. For example, a Canadian study found larger socioeconomic differences in traffic injuries (in respect of both morbidity and mortality) in girls as compared to boys (Dougherty, Pless, & Wilkins, 1990), while Swedish studies on the contrary, found a similar social patterning for both sexes (Hasselberg, Laflamme, & Ringbäck-Weitof, 2004). A plausible

explanation may involve the socio-economic status of families that precludes parents/caregivers from sending their daughters to advance their schooling, but instead prefer to keep them home to assist with the domestic chores. In addition, boys also often enjoy more independence than girls in relation to freedom of movement (Morongillo & Lasenby-Lessard, 2007, Morongillo, Walpole, & McArthur, 2009; WHO, 2013). Also, some parents tend to apply different sex socialising roles with regard to their male and female children, and this may in turn increase female children's vulnerability to potential unintentional injuries (Schieber & Vegega, 2002).

In short, the study has highlighted the fact that childhood pedestrian deaths and injuries among the 0 to 14 year olds persist as a global health burden, especially in the LIMCs, and in particular, in Johannesburg, South Africa. An understanding of the magnitude, patterns, circumstances and neighbourhood influences in respect of fatal child pedestrian injuries by using global heuristic research and science, presented the space and opportunity for this study to contextualise and critically review a decade of empirical findings on fatal child pedestrian injuries among 0 to 14 year olds in Johannesburg for the period 2001 to 2010. Based on the research findings, the study proffered recommendations for future research and intervention, while advocating introspection and meaningful action.

The concluding chapter focuses on the salient findings of the study, and attempts to address the research aim and specific objectives. The chapter will integrate and synthesise the various research methods used, as well as the issues and challenges germane to fatal child pedestrian injuries in the City of Johannesburg, South Africa. In addition, from the conclusions reached, the study will identify implications for policy and childhood pedestrian injury and mortality prevention, highlight the limitations of the study, suggest certain key recommendations for

future research and action, and ascertain the contribution/s made by the study to the broader research imperative of child pedestrian injury prevention.



## CHAPTER SEVEN

### SUMMARY AND CONCLUSION

The study is unique in that it investigated the incidence and determinants of fatal childhood pedestrian traffic injuries in the City of Johannesburg over a ten-year period. The study identified several significant findings.

It would appear that childhood pedestrian mortality rates in South Africa are not on the decline. The findings of this study emphasised the *vulnerability of children aged 0 to 14 years* as pedestrians, as opposed to their vulnerability as motor vehicle passengers, and also in relation to child burns and drowning mortality. Among the 0 to 14 year olds, children in the 5 to 9-year age group are especially at risk as pedestrians, followed by the 0 to 4 year olds, and, lastly, the 10 to 14 year olds. This finding is in line with the findings of previous South African studies which identified the 5 – 9 year old group as the most vulnerable group.

When focusing specifically on *child pedestrian mortality in relation to child motor vehicle passenger mortality*, the study found that the annual average mortality for child pedestrians was much higher compared to that of motor vehicle passengers. In fact, the childhood pedestrian average mortality for the 0 to 14-year age group was twice the average mortality rate of child motor vehicle passengers for the ten-year period. Overall, the study found that children from all age groups are more vulnerable as pedestrians as opposed to being motor vehicle passengers. However, within the 0 to 14-year age categories, a comparison of the childhood pedestrian mortality rate with that of child motor vehicle passengers found that the

5 to 9 year age group recorded the highest average mortality rate for pedestrians but the lowest average for motor vehicle passengers.

As regards *pedestrian deaths in relation to non-traffic deaths (i.e. burns and or drowning)*, the study indicated that pedestrian traffic deaths were the leading cause of unintentional child mortality among the 0 to 14 year olds over the ten-year period. Pedestrians were consistently the most vulnerable for all the age categories, except for the 0 to 4-year age group, where burns and drowning dominated. Thus, this study confirms and reinforces that the prevention of childhood pedestrian injuries and drowning be accorded priority especially for the 5 to 9 year olds and the 10 to 14 year olds, while for the 0 to 4 year olds, the focus should rather be on the prevention of burn incidents and drowning.

The study also identified *the vulnerability of boys* as the findings revealed that childhood pedestrian mortality was disproportionately represented among boys. However, boys also exhibited higher burn and drowning rates as compared to girls. For pedestrian mortality, this finding was applicable across the 0 to 14-year age group, while a similar trend was evident when male and female pedestrian death rates in the specific age groups were compared. In children from birth to 14 years, males exhibited a 67% higher pedestrian mortality rate compared to females (10.79 deaths per 100 000 population for males compared to 6.45 deaths per 100 000 population for females). Among children aged 0 to 4 years old, the rate of pedestrian death for males was 1.56 times the rate for females; for children aged 5 to 9 years old, the male rate was 1.80 times the female rate, and for children aged 10 to 14 years old, the male rate was 1.66 times the female rate. Males also reflected higher pedestrian and motor vehicle passenger mortality rates than females for children from birth to 14 years.

Alternatively, female motor vehicle passengers in the 0 to 4 year age group displayed the highest mortality rate, followed by the 5 to 9 year old, and 10 to 14 year old age groups. However, substantively, there were no significant differences in terms of either age or sex in fatal childhood pedestrian injuries in relation to motor vehicle passengers. Therefore, children of both sexes, and belonging to any age group, are equally vulnerable to the risk of a pedestrian death when compared to dying as a motor vehicle passenger. The logistic regression analysis revealed that the risk of pedestrian deaths versus drowning was significantly greater, and the risk of pedestrian mortality was higher for males as opposed to females.

*Population group* is another significant predictor of pedestrian deaths. Black children demonstrated the highest average childhood pedestrian mortality rate – nearly double the rate for coloureds and three times the rate for Indians. In general, there were so few pedestrian deaths in the white group that it was not considered worth including these deaths for analysis purposes. Black children consistently recorded the highest pedestrian mortality rates over the ten year period.

When considering only the socio – demographic variables on child pedestrian mortality in relation to burns and drowning mortality, population group had a notable effect on pedestrian deaths. When comparing pedestrian mortality versus burns mortality in children aged 0 to 14 years for the various population groups, coloured, Indian and black children were all equally likely to die from pedestrian injuries relative to dying from burns. Moreover, with respect to pedestrian deaths in relation to drowning, children in the 0 to 14-year-old age group, as well as children from the Indian, coloured and black population groups, were at risk when compared to the white children for pedestrian deaths in relation to drowning. In addition, coloured and black children were approximately five times more at risk than Indian children when compared

to white children to die of pedestrian injuries as opposed to drowning, while Indian children were three times more likely than white children to be at risk of a pedestrian mortality as opposed to drowning.

In addition, population group also had a pronounced effect on child pedestrian mortality when both socio-demographic and circumstantial predictor variables were considered. This was exemplified by the fact that a coloured child was six times more likely than the children from the other population groups to die of pedestrian injuries compared to a motor vehicle passenger death. Infants and young children were more vulnerable to pedestrian deaths, than older children, when compared to motor vehicle passenger deaths. In other words, regardless of age, a child is more vulnerable to a pedestrian death compared to a motor vehicle passenger death.

*Temporal factors* had a noticeable effect on children. Disaggregated analysis showed that children are almost twice or three times more likely to die during the afternoon and early morning, than at night as pedestrians rather than as motor vehicle passengers, and, are also equally likely to die as pedestrians rather than as motor vehicle passengers on weekdays, and on over weekends. Infants/toddlers were also 67% more likely to die from drowning compared to children in the 5 to 9-year age group, and in relation to children aged 10 to 14 years old, as opposed to a pedestrian death, irrespective of the time of day, day of the week, and during a holiday or non-holiday. It is worth noting that children are always susceptible to pedestrian deaths irrespective of a holiday or non – holiday.

*Neighbourhood factors* also had a noticeable impact on child pedestrian deaths. The findings indicated that areas with high concentrated disadvantage, which is associated with low educational attainment, low household income, unemployment, informal dwellings, low

educational attendance, household density, and black residents, were positively associated with higher rates of child pedestrian deaths in the 0 to 14 year olds, and also among children in the 5 to 9-year age group, including females. In addition, the rates of black child pedestrian deaths were lower in areas with higher concentrated disadvantage, while the rates of black child pedestrian deaths were higher in areas with higher concentrations of female-headed households. Residentially stable areas (i.e. areas with less residential mobility) also displayed a positively significant association with child pedestrian deaths in the 0 to 4-year age group.

It is believed that the findings from this study provide a platform to revisit the evidence on the incidence, occurrence, determinants and neighbourhood features of childhood pedestrian deaths, which mirror a sombre yet realistic backdrop to the South African pedestrian safety context. Investing in sound, scientific, child-centred research that is supported by interventions that are appropriately tailored, and, which address the physical, social and geopolitical environments, inequality and inequity challenges that predispose children to fatal pedestrian injuries, would help both to lessen and even prevent further fatal childhood pedestrian injuries in Johannesburg. Childhood pedestrian safety is a human right, and a shared responsibility. Ultimately, children's lives do matter.

## **1. LIMITATIONS OF THE STUDY**

In this chapter, using the limitations of the doctoral thesis as a point of reference, the study will attempt to elucidate whether the aim of the research, and its intended objectives were achieved in relation to the study design, the data sources used, the target population under investigation, and the analysis methods used to interpret the findings. In addition, the study will try to ascertain whether the overall contextual logic has responded to the challenges intrinsic in fatal

childhood pedestrian injuries in Johannesburg, South Africa. Accordingly, the shortcomings identified will be expressed in terms of both general and methodological limitations

## **1.1 General**

Since there is a conspicuous absence of a coordinated and cohesive national database for road traffic mortalities in South Africa, this doctoral thesis used data from the NIMSS, which is essentially the only available well-organised and managed secondary source of data on both intentional and unintentional mortalities in South Africa. However, secondary sources of data are constrained by their own limitations. A major challenge with regard to this data source was the missing mortality data on both the demographic and circumstantial variables, the absence of which could have compromised the integrity and outcome of the analyses related to each of the objectives underpinning this study.

Moreover, the omission of unseen forensic cases may also contribute to a misrepresentation of the total number of mortalities. Up to 2005, the NIMMS had extensive coverage in urban South Africa; however, thereafter data capturing was limited to the forensic services in the Gauteng region. The reason for this was the presence of several challenges linked to the management and coordination of the data capturing process, including the shortage of skills and capacitation among forensic service staff, the lack of resources at these facilities, and the fact that the recording of data was seen as additional work that compounded the existing workload.

In addition, the NIMSS data does not capture the precise manner and location of the mortality (i.e. circumstances surrounding the mortality, such as how, when, why, what, and who, and the exact location of the incident) because the person/s responsible for recording these details may not have provided comprehensive reports, which could be attributed to a lack of training and

capacitation in documenting the details of a mortality. Furthermore, when a death occurs at a particular scene, it may be documented as having taken place, there but may not be necessarily dealt with at the forensic services to which it has been assigned. Alternatively, this may result in a missing variable which ultimately lead to it being lost in the system and or not being captured or recorded by the NIMSS. Accordingly, missing data and uninformed responses can have an influence on both the quality of the data, and the planning of interventions for pedestrian injury prevention. In this environment, managing and participating together with the forensic services sector can be challenging, and requires ongoing correspondence, capacitation and monitoring to ensure that sound data is generated for epidemiological analysis.

A cause for concern in this regard is the uncoordinated response received from government agencies with regard to the scene of the mortality. Furthermore, since the NIMSS is the only source of mortality data in South Africa, lack of adherence to stringent data recording and capturing protocols could compromise its quality and assurance.

At the time of the study, rural data was unavailable; however, since 2009, the NIMSS has incorporated some rural data which was captured in the Mpumalanga province. In addition, some studies have recently been conducted looking at urban and rural differences in intentional and unintentional mortalities in South Africa. Further research using both these data sources could enhance the evidence base on child pedestrian deaths in South Africa.

The focus of this study was on children in the 0 to 14-year age group, and precluded other vulnerable groups such as pedestrians aged 15 years and older. As a global health challenge, childhood pedestrian injuries presents their own unique aetiology, and as such require further investment and research to mitigate their fatal effects.

The study also considered the effects of neighbourhood characteristics on childhood pedestrian mortality. These have been recognised as a potential threat to the safe mobility of children, but have not yet been analysed and documented extensively in South African studies.

The NIMSS subsequently continues to cover the City of Johannesburg from 2001 to date and, therefore, in meeting the other objectives included in this doctoral thesis, data from 2001 to 2010 was used. It is important to mention that the NIMSS data can be used to facilitate much-needed advocacy, engineering, enforcement and policy development initiatives for the prevention of childhood pedestrian mortalities and injuries.

## **1.2 Methodological and Analytical Challenges**

In order to address objective four, an ecological design was used to assess the effects of neighbourhood characteristics on childhood pedestrian deaths in the City of Johannesburg. The analysis was to some extent limited in its application, because it did not account for the evolving transformation of neighbourhood characteristics both over time, and during the period of this study.

During the time of the study, as a result of rapid urbanisation, the City of Johannesburg had mushroomed in size, and had experienced considerable population turnover and migration, all of which could have contributed to variations in neighbourhood-level features including neighbourhood boundaries. Since the neighbourhood characteristics were extracted from Census 2001, and because of the substantial lag between the census 2001 data and the pedestrian data pooled over the ten-year period from 2001 to 2010, it is uncertain how this may have influenced the outcomes. It is therefore proposed that longitudinal studies could capture the changes in community structure in Johannesburg, and such changes could also have an



influence on childhood pedestrian deaths, as well as ascertaining the structural features that persist over time.

The exclusion of 38.5% of pedestrian cases (i.e. a total of 413 out of 672 pedestrian cases were used for the neighbourhood analysis, thus omitting 259) from the analyses resulted from the fact that information on the suburb where the pedestrian deaths occurred was missing, and it appears that the data may not have been captured in detail. Moreover, the diffusion of some of the neighbourhood areas in the study can be attributed to the lack of specificity in the pedestrian data, which could in turn have affected the results, particularly with respect to spatial autocorrelation.

When considering the significance of analysis for the age category 0 to 11 months in terms of the following variables, namely, population group, sex and time, no statistically significant outcome in terms of risk for infants younger than 1 year was identified. Conceptually it may therefore appear appropriate in terms of analysis to separate the 0 to 4-year age group into infants – 0 to 11 months, and toddlers – 1 to 4 years. Nevertheless, in terms of risk analysis, this age categorisation was found to be insignificant, and therefore the age category for infants (0–11 months) was represented overall in the 0 to 4-year age group, which is also one of the age categories used by the WHO within the 0 to 14-year-old age category. Therefore, in this thesis, children in the 0 to 4-year age group were referred to as infants/toddlers for the purposes of analysis and discussion.

Finally, the results of this research cannot be generalised or extrapolated to other cities in South Africa. Previous studies have revealed that the incidence and characteristics of childhood pedestrian deaths in the 0 to 14-year age group differ across South African cities (Donson,

2005; Sukhai, 2003) and, moreover, that the neighbourhood infrastructural characteristics are distinct in every South African city. Nevertheless, with due regard to the context and analysis that have been presented in this thesis, it has to be accepted that addressing the preponderance of childhood pedestrian deaths in the Johannesburg and South Africa is cause for concern.

## **2. RECOMMENDATIONS FOR FUTURE RESEARCH AND ACTION**

In this chapter, a number of research issues and priorities were identified. Nevertheless, since the phenomenon of childhood pedestrian injuries is multifaceted and complex, the list is not intended to be exhaustive. In order to generate attainable policy strategies for both the reduction and prevention of child pedestrian injuries, the following pertinent issues should be considered:

- Contending with incomplete and limited data on child pedestrian exposure and injuries.
- The lack of and need for education, capacitation and awareness among children, caregivers, drivers, researchers and policymakers.
- Indigenous and culturally socialising practices and belief on sex.
- Unpacking the relationship between SES, poverty and child pedestrian injury.
- Disentangling the effects of neighbourhood characteristics, such as concentrated disadvantage and the socio-political built environment.

Moreover, an examination of the following concerns as potential research opportunities and strategies may go a long way to reducing and ultimately preventing fatal child pedestrian injuries in the City of Johannesburg, and in South Africa at large. It is proposed that such research include developing a consistent measure of injury risk, broadening the repository of pedestrian–vehicle collision data, conducting systematic and transdisciplinary research, disentangling demographic nuances, and presenting alternative paradigms for studying risks to

childhood pedestrian injury. Such research has the potential to produce novel injury prevention initiatives and control measures among high-risk populations in Johannesburg. As Laflamme and Diderichsen (2002) and Johnson et al. (2004) have concluded, the mechanisms of traffic injury risk remain poorly understood.

## **2.1 Education, Capacitation and Awareness**

*Evaluate interventions to assess whether the education, capacitation and attitudes of caregivers and drivers prevent and reduce child pedestrian injuries*

This study has highlighted the increased incidence and high rates of fatal child pedestrian injuries in children between 0 and 14 years of age. Accordingly, it is concluded that future research and prevention efforts should target the specific circumstances identified in this study that lead to children's exposure to traffic.

This can be achieved through interventions that consider a more comprehensive strategy, encompassing the education and capacitation of caregivers (i.e. training in supervisory skills that equip caregivers to understand the behaviours that are associated with the different stages in a child's development) and drivers and novice drivers (i.e. inculcation of knowledge on the various phases of cognitive development in children, and how to respond to their behavioural impulses in navigating complex road traffic systems). Simultaneously, the learner driver training manual should be revised to include simulated driver behaviour and responses in varying traffic scenarios. In addition, the age for obtaining a learner driver's licence should be extended and a capped kilometre driving distance should be implemented prior to issuing an accredited driver's licence.

## **2.2 Advocacy, Lobbying and Policy Initiatives**

*To describe and examine whether introducing safe walking, cycling and school routes in collaboration with communities and local government promotes community cohesion and safe mobility in neighbourhoods*

In this study, the evidence would seem to support the notion that the high rates of childhood pedestrian fatal injuries may be associated with scarce resources (i.e. lack of capacitation and skilled traffic personnel), speeding and poor driver behaviour, disregard of traffic laws and minimal traffic law enforcement. This is an extremely worrying phenomenon in Johannesburg, South Africa and other LMICs (WHO Afro-Region, 2009). Future research and interventions should contemplate integrating the following considerations:

- Local governments should consider integrating pedestrian and bicycle projects in their transportation plans, and appoint coordinators to facilitate and monitor these plans.
- Pedestrian-friendly community designs and transportation choices should be introduced when developing policies on mobility.
- Community-based surveys should be conducted, and the empirical evidence can be used to develop educational and awareness campaigns and to disseminate safety information.
- Local communities should become involved in designing neighbourhoods that are more suitable for walking.
- Communities should lobby local government for funds in order to create safe walking and bicycling routes.

Moreover, the following factors could be considered in addressing child pedestrian mortality rates:

- The monitoring of vehicle maintenance.
- The stringent regulation of cell phone use when driving.
- The more frequent policing of drunk driving, particularly at recreational sites (i.e. outside night clubs, etc.).
- The design and manufacturing of motor vehicles with safety features that alert drivers to potential threats to pedestrian injury, and making these cars affordable to all.
- Reflectorising children's and adults clothing and schoolbags to increase their visibility during low-light conditions (which has proven successful in low-income communities in the rural areas of South Africa).
- Including children and caregivers on road transport committees – such committees should be commissioned by government at all levels of society, including at the community level.
- Preventing children from walking long distances to access essential facilities such as schools, hospitals and public spaces, particularly because the study indicates the vulnerability of children 0 – 14 years old.
- Addressing the relationship between crime and child pedestrian behaviour in high-risk communities so that all children are able to feel safe walking in their neighbourhood (this requires collaboration and partnering with a network of various agencies to disseminate safety messages in communities, and implement initiatives that enhance the social environment in communities).

Studies by Killingsworth and Schmid (2001), Henson and Petch (2000), Safe Kids (2006), Vadeby and Forsman (2014), and Venter (2000) discussed similar initiatives.

### **2.3 Urban Environment, Mobility and Sustainability**

*To describe the effects of poverty, neighbourhood characteristics and the socio-political built environment and modifying influences on child pedestrian safety and overall mobility in a low-income setting; and*

*To conduct longitudinal studies on the effects of poverty, neighbourhood characteristics and the built environment in the City of Johannesburg on child pedestrian injuries among 0 to 14 year olds*

As discussed in many studies, much of the research on pedestrian injury focuses on the characteristics of the physical environment, while to a lesser extent analysing the role played by socio-political environments in injury. Elements that reflect a city's priorities, the organisation of a neighbourhood, as well as the community norms and individual values, may all influence behaviour and exposure to risk. Although some research has focused on pedestrian behaviour, it is possible that the disparate rates of pedestrian injury among low-income communities are related to differences in driver behaviour, and therefore it is important to comprehend the way both drivers and pedestrians perceive their environment, as well as the behavioural decisions they make based on those perceptions.

In addition, research should consider variations in police behaviour and enforcement. In low-income settings, unemployment may be widespread or erratic, particularly in female-headed household. Accordingly, affordable childcare in the form of after-school and weekend programmes at schools, community centres and other community facilities for example, would provide an option for those parents who do not wish to leave their children unsupervised. In low-income settings, children often use the streets as recreational spaces, which can endanger their safety. By providing and maintaining designated safe public play spaces such as parks,

playgrounds and recreation facilities, children would have space to play in a more protected environment.

For safe walking/mobility, reducing vehicle volumes and speeds can be achieved through street design changes such as the narrowing of streets, the separation of pedestrians from vehicular traffic, reducing the number of vehicle lanes, and the addition of street lighting, bicycle lanes and other “buffers”. Furthermore, pedestrian safety can be enhanced through infrastructural support such as extended signal crossing times, pedestrian islands, wider and more evenly paved sidewalks, high visibility crosswalks, raised pedestrian humps and pedestrian signage.

Finally, local municipalities and cities or other local jurisdictions can demonstrate the importance of pedestrian safety through the enforcement of traffic laws, focusing specifically on the pedestrian’s right of way, and speed limits by introducing passive environmental measures (i.e. traffic calming), enforcement of speeding throughout the year, and not just during school holidays and/or general public holidays. Finally, reducing speeds in residential areas, as well as near schools and public and recreational areas, to 10 to 30 kilometres per hour.

Since residential streets signify the vast majority of public space in most communities, it is crucial that these spaces are safe for all people to walk and play in without the threat of being injured. Several changes to the risk modifying factors would likely reduce childhood pedestrian injuries, specifically in low-income communities. Future research on the interplay between these environments and behaviour is therefore imperative. Protecting child pedestrians from injury requires a multifaceted approach that includes education, advocacy and engineering for a safer walking environment with a focus on low-income communities (Henson & Petch, 2000;

Hyder, Allen, Di Pietro, Adriaola, Sobel, Larson, & Peden, 2012; Johnson et al., 2004; Schwebel, McClure, & Prim, 2014).

## **2.4 Broadening the National Database and the Scope of Pedestrian-Vehicle Collision Data**

*To assess whether integrating and centralising multimodal systems of pedestrian–vehicle collision and mortality data will enhance our understanding of pedestrian injury patterns, and inform sound and enforceable transport policy decisions*

This study made use of the NIMSS, the limitations of which have been highlighted earlier, and to recommend the broadening and scope of pedestrian–vehicle collision data with the relevant stakeholders, so that the gaps intrinsic in the present system can be addressed. Firstly, a more comprehensive account is clearly needed of the context in which a childhood pedestrian injury occurred. Currently, police report of pedestrian–vehicle collisions provide little or no information about the road characteristics, driver behaviour and pedestrian behaviour. These variables are critical to a more in-depth analysis and understanding of pedestrian event and injury. Such reports should also include information about the traffic control system, the signal phase, signage, sidewalk condition, crossing conditions and other aspects of the road environment.

Collision reports should also include, if possible, vehicle speed, driver distraction, aversion attempts, and other aspects of driver behaviour. Accordingly, the presentation of a more comprehensive picture of the pedestrian would greatly enhance our understanding of injury patterns. Alternatively, information gathered by those responsible for documenting the injury should include pedestrian movement, size of the individual, was the pedestrian clearly visible



or not, and in which vicinity and possible direction was the pedestrian walking, and activity. Moreover, conflicts, or near misses, can also be used as surrogate measures for collisions. Since these are not commonly reported, they could be observed and reported by witnesses or bystanders.

Secondly, information is also needed about non-hospitalised and non-severe pedestrian injuries including other unintentional injuries such as burns and drowning, since these may display characteristics that differ from those that result in hospitalisation, and would thus add to our understanding of the different circumstances in which injury occurs.

Thirdly, pedestrian injury records, whether hospital-based (casualty or emergency records, ambulance services, police reports, insurance claims (which respect anonymity) or other sources should be gathered in a central database. These would create a more complete picture of the scope of pedestrian injury, since there is a significant number of people in health records that do not appear in police records. Moreover, there are some people who do not appear in either health and police records. This would help to obtain an idea of the real costs involved which could in turn help to build the case for investment in road safety. Additionally, to consider research that examines the under reporting of injury mortality data by conducting ‘verbal autopsies’.

Fourthly, a revision of the traffic enforcement laws may be needed, along with additional police training on pedestrian safety laws and collision reporting. As discussed above, pedestrians are often erroneously blamed for collisions, both by police and drivers. In the case of child pedestrians in particular, drivers and government should be held responsible for pedestrian safety. Training would help to ensure that the police understand pedestrian rights and

responsibilities and apply the law consistently. Additional resources should also be invested and targeted for increased enforcement of pedestrian safety laws.

More importantly, we need more advanced, user-friendly tools and systems for measuring pedestrian activity. The lack of data on pedestrian volumes, and the number of walked trips generated by surveys further precludes a realistic analysis of relative risk. On a national scale, surveys are needed to gather more information from a larger population, especially low-income households, indigenous and non-English speakers and children. On a smaller scale, more localized business and community or neighbourhood-based pedestrian measurement methods such as video analysis, automated detection systems and hand counts could be applied.

Ideally, efforts should focus on developing consistent methods of measurement across locations. Finally, in future investment should be made in evidence-based studies and the capacitation of researchers. A multidisciplinary team should be formed, that is attuned to road traffic injury, mobility, road design and transportation studies, in order to design road systems in tandem with communities that prioritizes the safety of pedestrians, and lessens the emphasis on motorisation as a panacea to safety, health and economic development (Hyder et al., 2012; ITF, 2012; Johnson et al., 2004; Lee, Cripps, Fitzharris, & Wing, 2014; Roberts, 1997).

## **2.5 The Need for Systematic and Transdisciplinary Research**

Previous and current research has predominantly focused on the nature and scope of the childhood pedestrian injury problem; however, it is essential to gain a comprehensive understanding of the determinants of risk, and the protective factors that moderate the risk of pedestrian injuries so as to enable the development of effective targeted interventions. It is therefore essential to enlarge and strengthen the evidentiary basis for action, by focusing more

on systems research (i.e. identifying the determinants of risk taking, and the risk and protective factors for injury and their environs), including the testing of interventions which can then lead to effectual research, that is, interventions that reduce or prevent pedestrian injury, and which ultimately translate into action and dissemination. The latter is referred to as “diffusion research”; that is, developing and promoting the application of “best practice” interventions that are easily adapted, are replicable and are sustainable within the context (Morengiello, 2003).

## **2.6 Understanding Demographic Nuances in Research**

This study, in common with many previous studies, posits that age and sex are both determinants of childhood pedestrian injuries with risk-taking being more evident in male children between the ages of 5 and 9 years old. Studies indicate that females are primarily concerned with the possibility of injury, whereas males are willing to take risks and are perhaps more accepting of risks while tending to focus more on the severity of the injury that could occur. Other studies allude to the socialisation of males and females by caregivers with respect to the independence and expectations of children’s behaviour.

Further research could explore children’s knowledge, attitudes, cognition, emotions and actions they associate with, if they were traumatised by a pedestrian injury. Once these lessons are identified, age and sex appropriate interventions can be tailored to promote their safe mobility. Roberts (2007) alludes to the fact that children have always been blamed for pedestrian crashes, and not the driver, or the car, and, he associates this blaming of the victim with the socio-political context or status quo.

Hyder, Puvanachandra and Allen (2013) suggests the development of a consistent measure of injury risk, namely, risk to a pedestrian injury. Such a measure includes injuries per walk trip, injuries per time spent walking or per distance walked, or, for motor vehicle crashes, kilometres or distance travelled. This would however require innovative pedestrian measurement tools and injury data. Future studies that engage in pedestrian research should consider using a standard measure of injury risk that would enhance the ability to compare research results, and analyse injury across time, place and income groups.

## **2.7 An Alternative Perspective on Studying Risks to Childhood Pedestrian Injury**

This study attempted to provide a socio-ecological systems approach/lens, by exploring individual, population and neighbourhood factors that predispose children to pedestrian injuries. Although social scientists (psychologists, anthropologist and sociologist) have integrated some semblance of a socio-ecological approach by moving beyond the individual and or environmental correlates to childhood pedestrian injuries, it may be more promising to locate pedestrian injuries within a more diverse socio-ecological context that generates a more comprehensible understanding of the behavioural and non-behavioural factors that influence injury risk. In so doing, the knowledge of and evidence base for the development of injury prevention and control initiatives targeting manifold levels of the contributors of risk (individual, family, community, neighbourhood, cultural, organisations, society and populations) would be enhanced (Bronfenbrenner, 1998; Morrengiello & Schwebel, 2003).

Further research could be used to develop creative techniques when planning the infrastructure and the environment. These could include the integration of the traffic, police records and census databases with the mapping system, for example, linking physical data on roads and activity centres with the child injury database, so that injuries may be viewed and analysed in

relation to physical features such as major roads and or schools. This would allow both interaction and conflict to be studied at the micro-level, as well as the use of a combination of databases (i.e. GIS mapping, casualty data) that permits researchers to more directly identify those factors that determine injury trends over time.

## **2.8 Research that Tackles the Disparities in Injury Risk**

This and other studies on fatal child pedestrian injuries strongly suggest a significant relationship between injury, and children below the age of 18 years living in poverty and deprived communities and low SES. Morriengeillo (2003), and Wazana and colleagues (1997) all mention the fact that rigorously conducted studies that examine living in poverty, deprived communities and low SES, and the effects these factors produced are lacking. For example, is child injury related to poverty primarily because of greater exposure to hazardous circumstances, or are there parenting norms (i.e. child rearing and supervision practices), family factors (e.g. value placed on risk taking), community factors (e.g. social norms about child independence), indigenous/minority populations and ethnic and cultural diversity that are related.

Another issue raised by Hyder and colleagues (2013) is our understanding and measurement of SES. Researchers use varied measures of SES, including family income, parent's occupation, education and other composite indices. Given the apparent relationship between pedestrian SES and injury, it is important to understand what factors are involved in this relationship, and therefore researchers are encouraged to use and or develop a consistent measure of SES, that would allow for the analysis of variation/s in injury while controlling for SES, since this is currently rarely done. Further research is also warranted to tackle the disparate risk and inequality in childhood pedestrian injury.

The main findings of this thesis postulate several risk factors and contextual drivers that may be attributed to childhood pedestrian mortality and injury. Future directions for research and action on the prevention of childhood fatal pedestrian injuries have been recommended. Hence it is time that a shift in the research paradigm and action is needed that is child-centric, and also prioritises child pedestrian safety.

### **3. IMPLICATIONS FOR PREVENTION**

In this study, the main findings reflected high rates of child pedestrian deaths in Johannesburg, and therefore have important implications for the future design and implementation of prevention strategies. Moreover, the determinants associated with fatal child pedestrian injuries require a holistic approach that will effectively curtail the ongoing magnitude of childhood deaths in the City of Johannesburg. This will entail collaboration between the city and its constituencies in developing a participatory pedestrian and road transportation systems approach within a multidisciplinary context. This systems approach should use reliable empirical data to inform policies and decisions when designing and planning pedestrian interventions.

The findings indicate that interventions to prevent fatal child pedestrian crashes are crucial, and should essentially focus on children aged 0 to 14 years who reside in low-income communities, and under conditions of concentrated disadvantage. Any child pedestrian prevention programmes and initiatives that are developed should embrace a participatory approach that will enhance safe pedestrian behaviour in communities. A review conducted by Davis and Quimby (2003) promoting road safety in LICs through community education programmes, used participatory research methods as a significant aspect of the research strategy. This engaging approach enabled various ways of examining road safety issues

amongst vulnerable groups who may not have access to formal education, or benefit from centrally managed improvement programmes and initiatives.

### **3.1 Improving and Strengthening the National Mortality Surveillance Data System**

Currently, the NIMSS is the only database that generates mortality data for both intentional and unintentional fatal injuries in South Africa. In recent times, both urban and rural data has been captured and integrated into this database. NIMSS data is available for public usage, and has been used to develop indicators for intervention and policy development by various sectors of national government and the media to draw attention to the burden of mortality in the country. However, as explicated previously, there are several shortcomings in the functionality of this vital database.

In order to strengthen this database and enhance its use, government should consider creating a centralised coordinating structure, the task of which will include the coordination of all the agencies that record mortality data, namely, police services, hospital emergency/trauma units (both public and private), toxicology departments and forensic service laboratories in the City of Johannesburg, and integrating these data sources into one comprehensive database.

This centralised structure must be provided with the necessary infrastructural and financial support, so that it can distribute the resources required to all the agencies that record mortality data, thus ensuring that their operational demands are met, and that sound data is available on request by government and its constituencies in order to respond to the health and safety needs of the city. In order for such a system to function efficiently, training and capacitation with regard to the capturing, recording and management of data must be made available to all agencies and their staff that feed data into this surveillance system. This approach could start

out as a pilot initiative which, if successful, could be expanded to both the City of Johannesburg and other cities in South Africa.

An investment in and commitment to a coordinated surveillance system, thus providing access to reliable data, augurs well for injury policy and prevention initiatives. One of the many challenges confronting countries, particularly in LICs, is the lack of a reliable surveillance system, which hinders the planning and advocacy of safety promotion programmes. Previous studies have shown that reliable data systems are essential for understanding the needs and outcomes of child pedestrian injury, and to inform and support effective implementation.

The availability of reliable data systems can support knowledge translation by establishing the magnitude of each problem locally, and documenting the effects of the interventions. Underreporting, definitional issues related to traffic deaths, poor linkages, and a lack of standardisation between data sets, as well as evidence of all unreliable data sources, result in challenges being experienced in the analysis of road traffic injury outcomes. In China, a comparison of the four national-level data systems uncovered contradictory road traffic injury estimates and deaths. In Egypt, data systems were found to lack data on severity and displayed limited coverage and poor standardisation across disparate surveillance systems. The NIMSS has been confronted with similar data system challenges.

In future, mortality and health care-based surveillance systems, police reports and government registries could play a substantive role in data collection in LMICs. Accordingly, investment in sustainable national surveillance systems is deemed necessary to provide funders, policymakers and multisectoral partners with current and reliable information for evidence-based decision-making when planning injury prevention initiatives. In addition, there is also a



need to recognize the importance and contribution of both quantitative, (i.e. analytical) and qualitative studies, (i.e. anthropological and ethnographic), in understanding child pedestrian injury and mortality and its prevention. These qualitative methods may be costly, but can be justified with more creative and innovative research (Evaniew, Godin, Schemitsch, & Bhandari, 2014).

### **3.2 Designing and Developing Sustainable Community-based Programmes to Prevent Pedestrian Injuries in Children 0 to 14 Years Old**

Although there is a dearth of research studies on childhood pedestrian injury and mortality in the City of Johannesburg, South Africa and in LMICS, a concerted effort has to be made to develop the existing evidence base. There is increasing evidence to support the effectiveness of community-based injury prevention programmes (Turner et al., 2004).

Therefore, investing in resources and providing such programmes with support and commitment will permit more creative and comprehensive strategies to be implemented which could lead to significant outcomes. If multiple interventions were to be implemented over a period of time, it could allow injury prevention messages to be repeated and reinforced in different forms and contexts, and it could begin to develop and instil a culture of safety in communities (Turner et al., 2004).

The important components of community-based programmes that have been proposed should be realistic and achievable, and include a long-term strategy, including a need to develop valid and reliable indicators of impact and outcomes that are appropriate to the community context. In programmes where proxy measures are used for injury outcomes, it is important that there is clear evidence of the association between the proxy (e.g., hazard removal, knowledge gain

or behaviour change) and injury risk (Towner et al., 1996), and a focus on reducing traffic exposure in association with aspects of children's outdoor activities, while simultaneously balancing the goals of improving safety and preserving mobility.

Moreover, it is essential that indicators be developed to assess the safety culture, programme sustainability and long-term community involvement, effective and focused leadership, coalitions/multi-agency collaboration and visibility. In addition, local surveillance should be used to develop locally appropriate interventions that are tailored to the needs of the community, as well as culturally and linguistically appropriate messages that are developed and tested with the specific audiences in mind. Further, community-based participatory approaches to engagement, including an iterative process of monitoring and evaluating the cost-effectiveness of a programme, should be used (Turner et al., 2004).

Safety programmes should encapsulate a poverty alleviation and job creation component, especially in LICs, since this study and many previous studies have indicated that the risk of pedestrian injuries to children is quadrupled in low-income communities. Poverty is unfailingly one of the causes of child pedestrian injuries, and efforts to reduce socio-economic inequalities would be an appropriate public health approach to prevention (Roberts & Coggan, 1994).

Planning to make time is also essential to coordinate and consolidate existing networks and invite others to participate in this multi-agency network. However, it has not yet been established conclusively which programme strategies have a proven sustained impact on injury prevention. Unfortunately, community-based injury prevention programmes have been constrained by the lack of resources allocated to both their programme development, and accompanying appropriate and rigorous evaluation (Turner et al., 2004).

A possible way forward is to identify those components of programmes that are embedded in ‘best practice’ community-based injury prevention programmes. By enlarging the evidence base and including an array of properly evaluated community-based injury prevention programmes, it would then enable a more comprehensive perspective on the mediating and moderating environmental, cultural, geographical and political influences that characterise communities in Johannesburg, and also have an impact on population-level pedestrian injury rates (Spinks et al., 2004).

### **3.3 Urban Environment: Addressing the Socio-Political and Motorisation**

The main findings of this research reflect inequality in childhood pedestrian deaths in neighbourhoods associated with high concentrations of disadvantage. However, much of the available evidence on child pedestrian injuries has emerged from high-income countries, with little emanating from LMICs. Likewise, many of the existing strategies have been developed primarily from the perspective of preventing injuries to motor vehicle passengers, and scant consideration has been given to their effect on vulnerable road users.

In response to the burden of injury, a range of countermeasures which focus on the prevention of injury and the promotion of safety has been developed. These countermeasures vary from interventions that are either passive (protect the individual) or active (require the individual to change behaviour). Passive countermeasures are generally those that are integrated into the environment.

Despite an increased understanding of the association between the built environment and pedestrian injury outcomes, little attention has been paid to the possibility of injury reduction being achievable if safety and injury prevention is a priority in the design of built environments.

Integrating safety into the built environment requires a socio-political commitment and a partnership between government, industry and non-government players. Essentially, it requires institutions and agencies to make a dynamic shift from the status quo. Lobbying and advocacy are thus needed to ensure that governments move towards adopting and implementing strategies that prioritise safety and the built environment. The WHO – Safe Communities Network is an illustration of a safe community (Welander et al., 2004).

Arguably, as indicated in the findings, since pedestrians form the most significant proportion of road-traffic injury victims both in South Africa and worldwide, they should be a substantial, if not the foremost, focus of current national and global prevention initiatives. The success evident in cities such as Curitiba in Brazil, where public transportation systems, the integration of bicycle paths, and the introduction of pedestrian areas were prioritised, has resulted in reduced vehicular traffic, increased pedestrian activity, reduced pollution and safer environments (Stevenson, 2006).

Ideally and strategically, linking short-term goals to long-term strategies should be in relation to an emphasis on safety and other health outcomes in the development and design of the built environment. Moreover, the fact that children cannot walk and play safely, and indeed risk death in their surroundings, is evidence of the failures in the system, since the built environment is an integral part of that system. If citizens are to advocate for change, they will need to unite as one voice (Stevenson, 2006)

The systems approach alluded to in this study also encapsulates and proposes an eco-city approach, which in terms of cities, towns, suburbs and neighbourhoods are designed to enhance the health, safety and quality of life of individuals and, importantly, to maintain the ecosystems

on which they depend. This approach requires cities to be built for safe pedestrian and non-motorised transport use (including low-cost public transport), as well as to provide safe homes. Importantly, it promotes a systems approach in which safety (along with the other elements) is integrated into urban planning. With pedestrian injuries as one of the leading causes of death in childhood, and with the potential changes to the built environment, this could contribute significantly to a reduction in injury and death. This study has found that safety and injury prevention should be placed on the agenda of the decision-makers that have socio-political responsibility for the built environment (Stevenson, 2006).

In order to prevent child pedestrian injuries, our results provide a strong argument for the introduction of measures to reduce traffic volumes in urban areas. Such measures might include traffic management strategies that divert traffic away from residential neighbourhoods, and neighbourhood traffic calming schemes that reduce the volume of traffic on residential streets. Therefore, targeting the implementation of such schemes in low SES areas would probably be a prudent approach. Alternatively, the volume of traffic throughout the entire road network might be reduced by introducing transport policies that encourage a shift from the use of private cars to public transport for longer journeys, and to cycling and walking for shorter journeys. Children and their parents have traditionally been held responsible for the problem of child pedestrian safety. Our results and those of previous studies point to the responsibilities of the system in this regard (Roberts et al., 1995; Roberts, 2007).

In this study it was also found that poverty and low SES are also related to child pedestrian fatal injuries. Therefore, an increase in our understanding on the relationship between SES and child pedestrian injury risk is critical to efforts to encourage walking both as mobility and for

its health benefits. Studies have shown that SES affects the physical and social environments, which in turn affect behaviour, and accordingly may modify the risk.

This is particularly relevant for children who are poor, given the disproportionate risk of injury to child pedestrians, who tend to walk further and more frequently in low-income communities. Studies are limited by inadequate pedestrian exposure data, insufficient pedestrian injury data and a common measure of risk (Johnson et al., 2004). Thus, improving the quality of information gathered from collisions, developing tools to measure pedestrian trips, and focusing research on understanding the interaction between SES, behaviour, exposure and risk could contribute to designing policies, that reduce and prevent pedestrian injuries in all children, especially among the disadvantaged (Agran et al., 1998; Posner et al., 2002).

Furthermore, coalitions working with eco-friendly environments may be better equipped to determine what constitutes safe neighbourhoods, and what constitutes safe and affordable housing. In addition, to provide green spaces for people to enjoy where they live and work, and to rethink modes of transportation when travelling from one place to another. Residential stability also has an influence on child pedestrian safety. One study found that a strong factor in this regard is the movement of people into new neighbourhoods. Therefore, it is vital to consider designing environmental interventions that would enhance a more pedestrian-orientated family environment. Such measures should be constantly advocated and institutionalised so that less reliance is placed on individual behaviours (Leyden, 2003).

### **3.4 Policy Initiatives: Promoting Equity and Justice in Childhood Pedestrian Safety in the City of Johannesburg, South Africa**

This study has tried to elucidate that the burden of childhood pedestrian mortalities and injuries in the City of Johannesburg, and in South Africa is at a critical juncture, and cannot be overlooked, as is often done in attempts to improve health and other national priorities. The main findings have alerted the reader to the increased magnitude of childhood pedestrian mortality rates across all ages in the 0 to 14 year old category, and how the circumstances (i.e. sex, population groups and temporal), and neighbourhood determinants (i.e. concentrated disadvantage such as poverty, single-female-headed households), children's diminishing play spaces and urbanisation (built environment) have influenced child pedestrian mortalities over the ten-year study period in Johannesburg.

Although evidence-based strategies are available, governments are neither adopting nor implementing them. This implementation hiatus, although not unique to road safety, is detrimental if it continues to expose child pedestrians to RTIs, and unsafe road traffic environments (Hyder, Labinjo, & Muzaffar, 2006). A cursory review of the current NDOT policy strategic imperatives (SA Road Safety Strategy 2011–2020) highlight the need to address and develop several interventions intended to reach all stakeholders and segments of society, including youth and children, and rural and urban dwellers. However, some of these ideas have not been presented in appropriate and accessible language and style. Accordingly, projects are required that will change the attitudes and behaviour of all road users – drivers, passengers and pedestrians – reducing the “culture of impunity” of poor drivers, and using education channelled through the Department of Education. Unfortunately, it has been ascertained that owing to changes in the NDOT, most of these proposed actions have not come to fruition.

However, the study proposes that the following actions be implemented, some of which have a broader orientation, while others are more focused on untangling the socio-political context underpinning RTIs. Within a broader context, a central government agency could be identified to guide the national road safety endeavour, and or develop and consolidate an existing central structure, and, prepare a national road safety stratagem that includes a multidisciplinary research network and tactics of action.

A major policy implication is how to expand the existing expertise, and how to encourage collaboration between disciplines. This will require all those who work in injury control and prevention to:

- Develop skills in advocacy and politics, and be willing to take on difficult issues of equity and human rights.
- Assess the challenges, policies and institutional settings relating to road traffic injuries and the capacity for prevention in Johannesburg.
- Apportion the financial support and strengthen the human and social capital and resources needed to address the challenges.
- Implement specific initiatives to prevent motor vehicle crashes, minimising injuries and their consequences for vulnerable road users (i.e. child pedestrians), and investing in the evaluation of their impact.
- Support the development and empowerment of national capacity in the road and safety transportation sector.
- Conduct research on the risk and protective factors of pedestrian injury and control, and approaches to injury treatment.
- Design, implement and evaluate countermeasures and assess their effectiveness.



Road transportation policies also have to be cognisant of the impact of motorisation in the City of Johannesburg, and the class differences that separate car drivers and non-drivers. These policies should advance the safety of the child pedestrian in terms of the motor vehicle, and as a motor vehicle passenger. If there is consensus that development in high and low-income countries is meant to improve public health, then the need to reduce RTIs may eventually serve as a powerful argument when searching for intelligent transport solutions. For this argument to become effective, it must be made convincingly. Therefore, the discourse is pertinent, and must be heard (Borowy, 2013).

When developing policies, it is important to include community design that integrates socio-political environments and transportation choices. Poorer people are most at risk for injury, since they are the people with the “least power” and resources to improve an unsafe environment, even when the risks are known. Safety policies cannot be assumed, and to be effective, has to be the lived experience of the pedestrian. The planning of road networks should incorporate safety features into road design, and remedial action at high-risk crash sites, and contain overarching strategies for ensuring the development and maintenance of safe roads.

Legislation should be implemented that directs a portion of state transportation funds to safe pedestrian design in low-income communities, as well as for bicycle routes to school (Killingsworth & Schmid, 2001). Communities should be supported by local government in making their neighbourhoods safe, and more suitable for walking. Evidence has shown that in a city, pedestrians and bicycles are indicators of community cohesiveness, social capital, quality of life, and health.

Since this study has reflected high pedestrian injury rates in low-income settings, injury prevention policies and associated activities should therefore be implemented and contextualised as a broader social justice, equity and human rights issue. Systems need to be in place to ensure that these policies are effectively implemented (Evans and Brown, 2003; Mock et al., 2004; Killingsworth & Schmid, 2001; Carver, Timperio, & Crawford, 2008; Hewson, 2005; Hyder et al., 2012).

#### **4. CONTRIBUTION TO RESEARCH**

There is a scarcity of local, national and African studies and evidence on childhood pedestrian injuries and deaths among 0 to 14 year olds. Although intermittent studies on childhood pedestrian injuries and mortality among 0 to 14 year olds in some cities in South Africa were conducted in the late 1990s and early 2000s, there nevertheless remains a paucity of such studies. To date, no studies have been conducted specifically examining trends over time in Johannesburg, in terms of magnitude, occurrences, circumstances and the effects of neighbourhood characteristics on child pedestrian deaths over a ten-year period. In addition, limited or no studies were found that compared fatal child pedestrian injuries to motor vehicle passengers and non-traffic injuries such as burns and drowning among other unintentional injuries.

The current study has investigated childhood pedestrian deaths in the City of Johannesburg, South Africa with respect to the magnitude, occurrences, circumstances and neighbourhood characteristics among children from birth to 14 years from 2001 to 2010. The study has also shown that child pedestrian fatal injuries are the leading cause of mortality among 0 to 14 year olds in relation to other unintentional fatalities. The research also examined child pedestrian mortality in relation to motor vehicle passengers (traffic), and other significant unintentional

fatalities such as burns and drowning. This adds to the uniqueness of this study, as research on childhood pedestrian injuries generally only consider the influences of epidemiological risk factors, and the physical environment in attempting to understand the causality and moderators of injuries.

Few studies were found that investigated the effects of the social environment (i.e. protective factors such as social capital and community cohesion), neighbourhood characteristics, poverty, urbanisation and motorisation, including the built/urban environment on fatal child pedestrian injuries. This study has subsequently inferred that the physical, social and geopolitical environment has a significant influence on a child's predisposition to fatal pedestrian injuries. The current study has attempted to address these gaps, and has endeavoured to contribute to the existing evidence base on fatal child pedestrian injuries in Johannesburg, South Africa. This study therefore reaffirms the notion that pedestrian safety is a human rights issue, and more importantly, children's lives do matter.

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## APPENDICES

### Appendix 1: Ethical Clearance



14-05-2013

#### ETHICAL CLEARANCE OF A RESEARCH PROJECT INVOLVING HUMAN PARTICIPANTS

**Project:** Childhood Pedestrian Injury in South Africa: Magnitude, determinants and Perceptions

**Researcher:** Mr. A. Bulbulia

**Supervisor:** Prof. M Terre Blance (Dept. Psychology, Unisa)

The proposal was evaluated for adherence to appropriate standards in respect of ethics as required by the Psychology Department of Unisa. The application was approved by the departmental Ethics Committee with no additional conditions.

A handwritten signature in black ink, appearing to read "P Kruger", is shown.

Prof P Kruger  
*Department of Psychology  
College of Human Sciences  
University of South Africa*



University of South Africa  
Preller Street, Muckleneuk Ridge, City of Tshwane  
PO Box 392 UNISA 0003 South Africa  
Telephone: +27 12 429 3111 Facsimile: +27 429 12 429 4150  
[www.unisa.ac.za](http://www.unisa.ac.za)